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NRL Memorandum Report 157

**FIELD STRENGTHS OF SOME VLF
TRANSMISSIONS AND ATMOSPHERIC NOISE
MEASURED IN EUROPEAN AND ASIAN AREAS
MARCH, APRIL AND MAY, 1962**

[UNCLASSIFIED TITLE]

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and R. L. Schauer

RADIO DIVISION

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29 October 1964



U. S. NAVAL RESEARCH LABORATORY
Washington, D.C.

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ABSTRACT
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The Naval Research Laboratory is conducting an investigation of very-low-frequency (VLF) radio wave propagation at great distances and over a long period of time. The statistical relationship of the field strength of various VLF transmissions and atmospheric noise and the signal-to-noise ratios with the time of day and season of the year is being investigated. Between December 1958 and approximately March 1964 the subject propagation data has been recorded at the following sites: Hammerfest, Bodø and Varhaug, Norway; Rome, Italy; Haifa, Israel; and Karachi, West Pakistan.

This is the thirteenth in a series of quarterly reports, covering the fourteenth quarter since the program began. During the period covered by this report, March, April and May, 1962, Karachi was in operation the entire time, Haifa ceased operation at the end of March and Hammerfest became productive in April.

PROBLEM STATUS

This is an interim report on one phase of the problem. Work is continuing this and other phases.

AUTHORIZATION

NRL Problem R01-39
BUSHIPS Problem S-1888
SR 008-01-01-7028

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FIELD STRENGTHS OF SOME VLF
TRANSMISSIONS AND ATMOSPHERIC NOISE
MEASURED IN EUROPEAN AND ASIAN AREAS
MARCH, APRIL AND MAY, 1962

INTRODUCTION

The Naval Research Laboratory is conducting an investigation of very-low-frequency (VLF) radio wave propagation at great distances and over a long period of time. For this investigation, the field strengths of various VLF transmissions and atmospheric noise have been and/or are planned to be continuously recorded at several sites on the coasts of Europe and the Near East from December 1958 through approximately March 1964. Extension of the project through the spring of 1964 is primarily intended for obtaining coverage data on the Navy's new VLF transmitting facility at Cutler, Maine which commenced operation in January 1961. Information will continue to be obtained on the other VLF transmissions during that period.

The routine output data is being published in installments covering each quarter of the year, grouped according to the seasons. This series of reports will not contain an analysis of the data. Analysis and correlation of the data with various geophysical phenomena will be the subject of other reports. This report is the thirteenth in the series of these installments and covers the fourteenth quarter, the spring months of March, April and May, 1962. Reference 1 covered two quarters.

TRANSMISSION PATHS

During the period covered in this report, field strengths of VLF transmissions and atmospheric noise were recorded at Hammerfest, Norway, Karachi, Pakistan and Haifa, Israel. The precise locations of these recording sites are given in Table 1. The locations of the U. S. Navy VLF transmitters are given in Table 2.

A VLF recording site was installed in Karachi, West Pakistan in June 1961 and will be operated through March, 1964. However, due to the severe environmental conditions, other local problems, and the use of the unreliable instrumentation discussed above, many equipment outages resulted. As a consequence, consistent, usable data were

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not obtained for continuous periods of sufficient duration to justify processing until March 1962.

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TABLE 1

Locations of Data Recording Stations and Periods of Operation

<u>Station</u>	<u>Location</u>	<u>Period of Operation</u>	
	<u>Latitude</u>	<u>Longitude</u>	
Bodø	67° 16.5'N	14° 21.4'E	Dec 1958 - Sep 1960
Varhaug	58° 37.5'N	5° 37.8'E	Dec 1958 - Mar 1962
Rome	41° 51' N	12° 40' E	Dec 1958 - Aug 1960
Hammerfest	70° 39' N	23° 37' E	Jun 1959 - Dec 1959 Mar 1961 - Mar 1963
Haifa	32° 48' N	35° 2' E	Jun 1959 - May 1962
Karachi	24° 54' N	67° 2' E	Jun 1961 - Mar 1964

TABLE 2

Locations of U.S. Navy VLF Transmitters

<u>Station</u>	<u>Location</u>	
<u>Call Letters</u>	<u>Latitude</u>	
NSS	38° 59.1'N	
NPG	48° 12' N	121° 55' W
NPM	21° 25.5'N	158° 9.7'W
NDT	34° 58.3'N	137° 1.3'E
NAA	44° 38.9'N	67° 16.9'W
NBA	9° 3.3'N	79° 38.9'W

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DATA RECORDING AND PROCESSING METHODS

All field strength data reported herein were recorded using a 10-foot, vertical, monopole (whip) antenna. One such antenna is installed at each data recording station. A broadband antenna coupler is used to couple the antenna to AN/URM-139 and AN/URM-6 field strength meters which drive Esterline-Angus strip chart recorders. The whip antenna system is calibrated periodically using a loop antenna.

The U.S. Navy transmitters "locked key" for three minutes and, immediately preceding or following, are "off" for three minutes once each hour. It is during these periods that the subject data were recorded.

Atmospheric noise

The atmospheric noise field strengths reported are average values recorded once each hour during the three minute "off" period of the transmitters discussed above. The AN/URM-139 equipments have a nominal noise bandwidth of 41 cps while the noise bandwidth of the AN/URM-6 equipment varies between about 100 and 200 cps depending upon the frequency to which it is tuned. All atmospheric noise field strengths have been normalized to a bandwidth of 100 cps.

Signal Field Strengths

The signal field strengths given in this report are average values over the three minute "locked key" period recorded once each hour, and normalized to a radiated power of one kilowatt. The signal field strengths are calculated from the measurements of the average signal plus noise and the average noise made during the locked-key and off periods of the transmitters. The radiated power during each locked-key period is determined from a measurement of the average transmitting antenna current during each period and the average radiation resistance of the antenna. The radiation resistance values used for each transmitter are given in Table 3. The radiation resistance of each transmitting station is periodically measured and the value appropriately changed if necessary. Although the radiation resistance of NPG appears to have a seasonal dependency, an average value is used throughout

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the year since the effect on the radiated power is slight.

TABLE 3

AVERAGE RADIATION RESISTANCE FOR VLF TRANSMITTERS

Station	Frequency kc	Radiation Resistance ohms
NAA	14.7	0.078
NBA	18.0	0.069
NPG	18.6	0.079
NPM	19.8	0.072
NSS	22.3	0.134

Signal-to-Noise Ratios

The signal to atmospheric noise ratios for each hourly locked-key and off period reported are the ratios of the locked-key field strengths normalized to a radiated power of one kilowatt, to the average atmospheric noise field strengths normalized to a 100 cps bandwidth.

Transmitter Radiated Power

As previously stated, the field strengths of all transmissions reported herein have been normalized to a radiated power of one kilowatt. The radiated power during each field strength measurement is calculated by squaring the average transmitting antenna current measured during each locked-key period and multiplying by the average value of radiation resistance (Table 3). To determine the various propagation effects, it is necessary to normalize the data to a constant radiated power. However, for planning communication circuits

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and determining the reliability of the circuits, it is necessary to know the radiated power capability of each transmitting facility.

In Table 4 the average radiated power for each transmitter for each month is given along with the number of hourly periods during which the locked-key test was not transmitted. For approximately six hours each week, NPG operates with only half of its transmitting system for routine maintenance. Although these periods have been referred to as "half-power" transmissions, the reduction in radiated power during such operation is considerably more than 3 db. These "half-system" transmitting periods were not used in determining the average radiated power from NPG because normally the signal is undetectable at all the data recording stations during these periods. The NAA transmitter also operates periodically from half of the system at a reduction in radiated power of approximately 3db. Since these "half power" transmissions can be received at all of the data recording stations, they are not omitted in computing the monthly average radiated power, as is the case with NPG. In Table 4 the monthly average radiated power is computed separately for the full and "half power" transmissions.

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TABLE 4
MONTHLY AVERAGE RADIATED POWER

STATION	FREQ KC	MONTH YEAR	AVERAGE RADIATED POWER		#LOCKED-KEY PERIODS		
			KW	DB ABOVE 1 KW	FULL POWER	HALF POWER	OMITTED
NAA	14.7	Mar 62	*997.4(414.4)**	*30.0(26.2)**	617	39	88
		Apr 62	*853.0(408.0)**	*29.3(26.1)**	595	76	49
		May 62	*1015.9(412.6)**	*30.0(26.2)**	623	72	49
* Average radiated power for full power periods only							
** Average radiated power for "half power" periods only							
NPG	18.6	May 62	174.7	22.4	589	21	134
NPM	19.8	Apr 62	74.3	18.7	629	0	91
		May 62	85.4	19.3	492	0	252
NSS	22.3	Mar 62	145.2	21.6	712	0	32

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RESULTS

The data are reported in several forms as follows:

1. The mean plus and minus one standard deviation for the signal and the atmospheric noise field strengths and the signal-to-noise ratios for each hour of one day for a period of one month.
2. The mean for the signal field strengths and the signal-to-noise ratios for each hour of the day over approximately ten day periods of each month.
3. The probability distribution of the signal and the atmospheric noise field strengths and the signal-to-noise ratios for a period of one month.

NOTE: The probability distribution presented for the signal and noise data, separately, are not time correlated. That is, a high signal level did not necessarily occur simultaneously with a high noise level. Therefore, these two sets of data cannot be used for determining the signal-to-noise probability distribution. Graphs showing the true, signal-to-noise probability distribution are presented, however.

In processing the data included in this report, atmospheric noise field strengths are computed only for the hours during which a signal field strength is computed from a recorded locked key transmission. Ideally this occurs once an hour, every hour. Priority traffic and scheduled maintenance at the transmitter and emergency maintenance at the transmitting and receiving sites thwart efforts to attain the ideal situation. The actual number of recorded, locked key transmissions is indicated above each hourly plot on the monthly signal-to-noise ratio curves. These numbers apply to the signal and atmospheric noise field strengths as well as the signal-to-noise ratio calculations.

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During the period covered by this report, all three receiving sites, when operating, recorded NAA, Haifa, which was shut down in early April, also recorded NSS. No usable data were recorded at Hammerfest until April at which time NPM and NPG were recorded in addition to NAA. The NPG data at Hammerfest were insufficient until May.

Additional information about atmospheric noise at many locations around the world and for the same period covered by this report may be found in reference 2.

Figures 1 and 2 may be removed from the report and used for interpolation of the appropriate graph scales.

In March, 1962 new antenna couplers were installed at the Hammerfest and Karabhi sites. The method used for determining the antenna factor with the new coupler was different than the method used with the old coupler by a factor of 6db. Unfortunately this change was not incorporated in the computer program. As a consequence, all of the signal and noise field strengths from those stations are in error from that date. The correction factors are noted on the affected curves. THE SIGNAL-TO-NOISE RATIO CURVES ARE, OBVIOUSLY, NOT AFFECTED.

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TABLE 5
FIGURE NUMBER INDEX OF THE INCLUDED DATA

	<u>MARCH</u>		<u>APRIL</u>		<u>MAY</u>		
	NAA	NSS	NAA	NPM	NAA	NPG	NPM
HAIFA	3-9	10-16					
HAMMERFEST			17-23	24-30	31-37	38-44	45-51
KARACHI	52-58		59-65		66-72		

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REFERENCES

1. NRL Memo Report 1478 - 5 December 1963, by W. E. Garner, F. J. Rhoads, E. J. Elwood, III, and R. L. Schauer.
2. "QUARTERLY Radio Noise Data - March, April, May 1962", by W. Q. Crichlow, R. T. Disney, and M. A. Jenkins, National Bureau of Standards Technical Note No. 18-14, dated 9 August 1962.

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NORMALIZATIONS

The Field Strengths Of All Transmissions Are Normalized To A Radiated Power (P_r) Of One Kilowatt.

Atmospheric Noise Field Strengths Are Normalized To A Bandwidth of 100 Cycles Per Second.

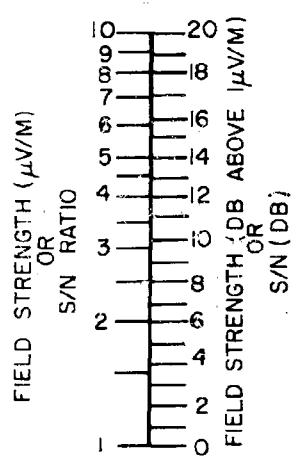


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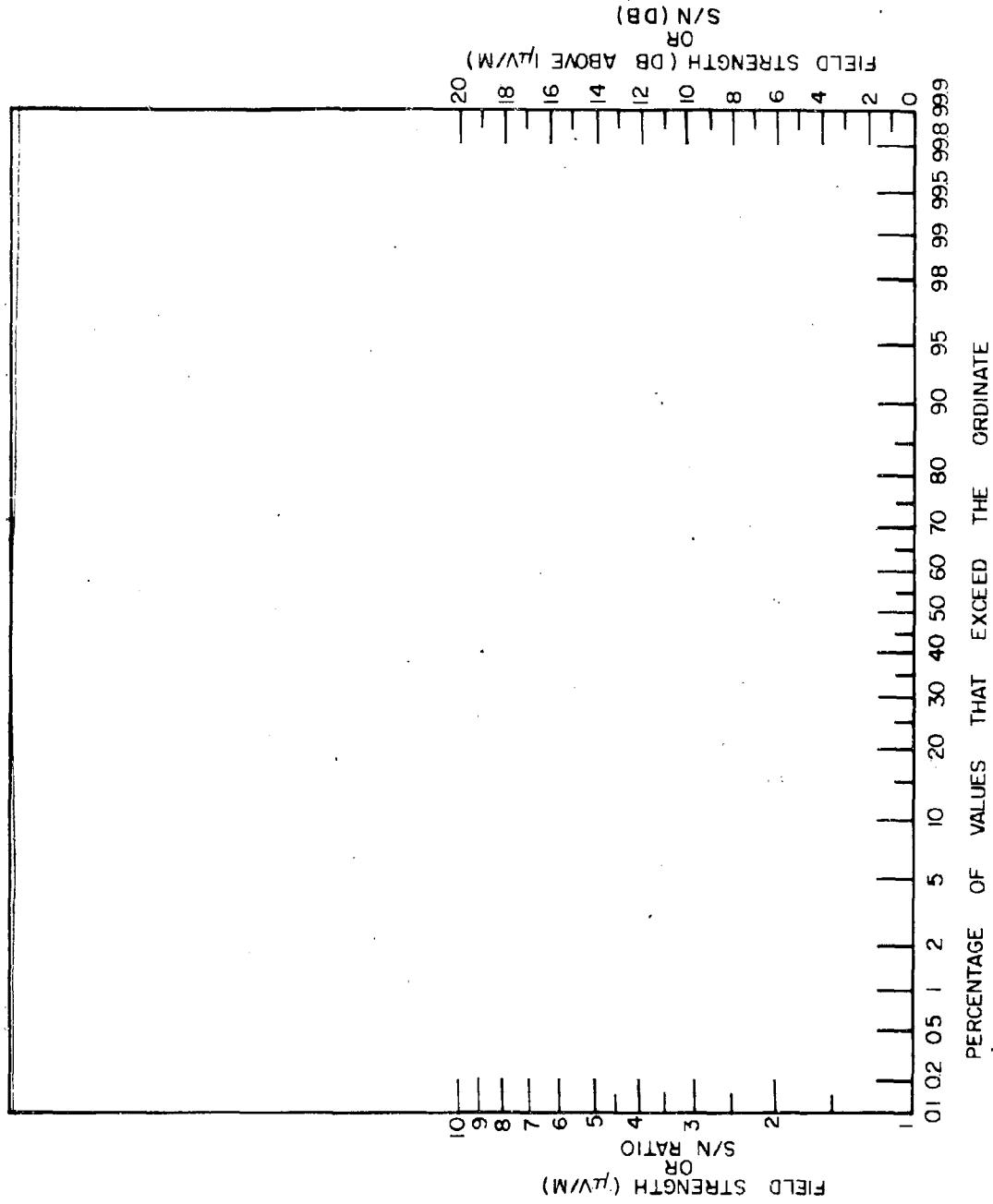


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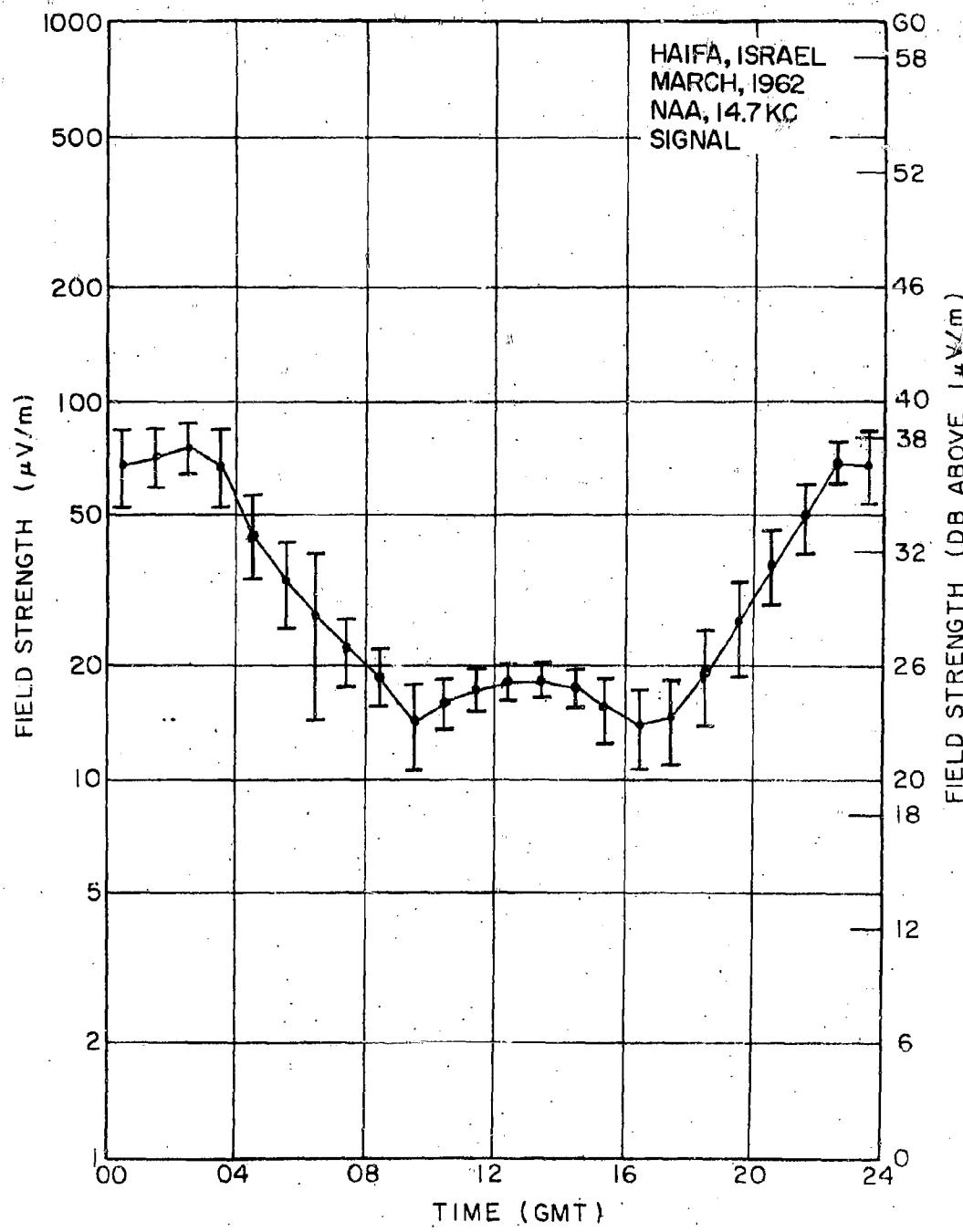


Figure 3

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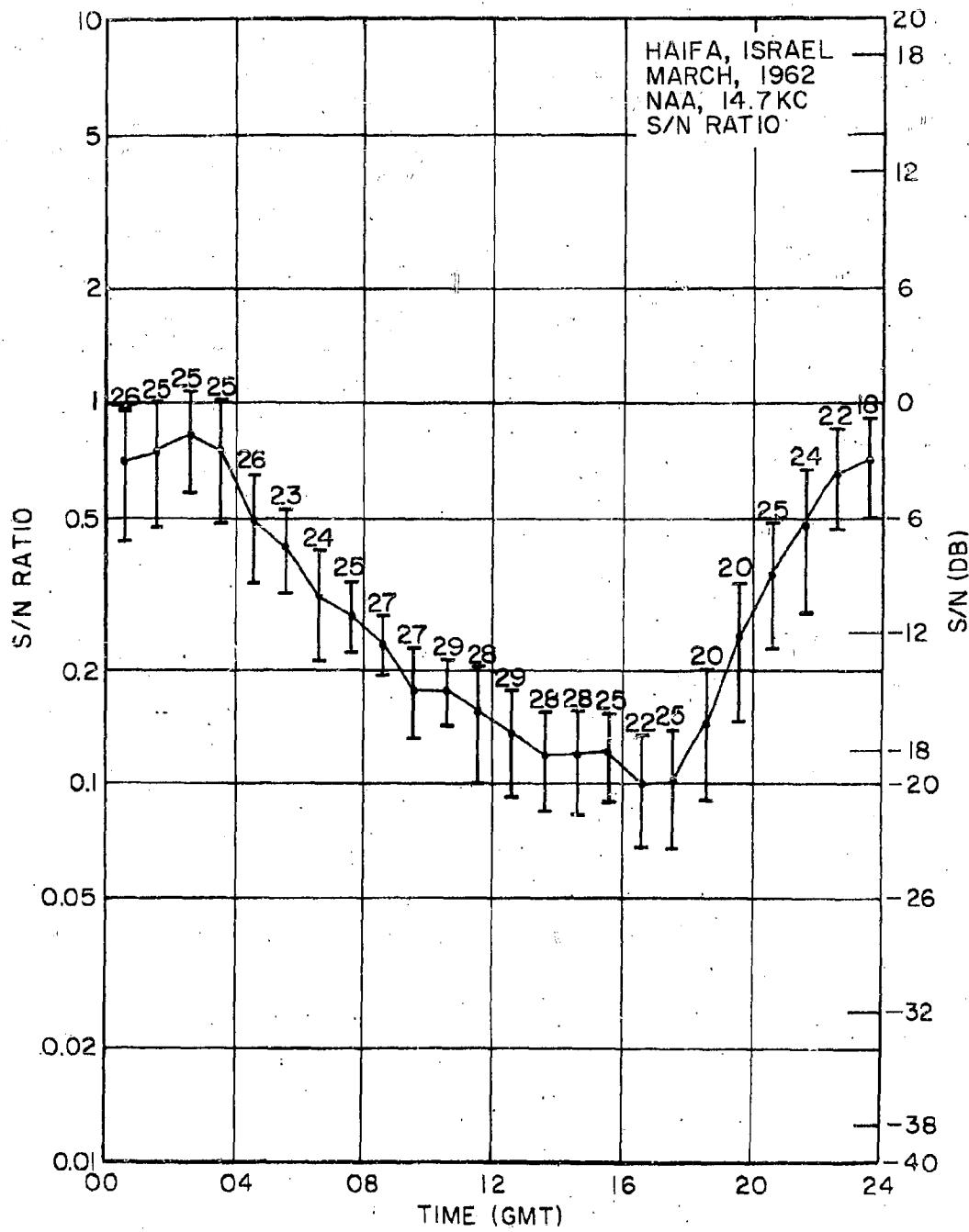


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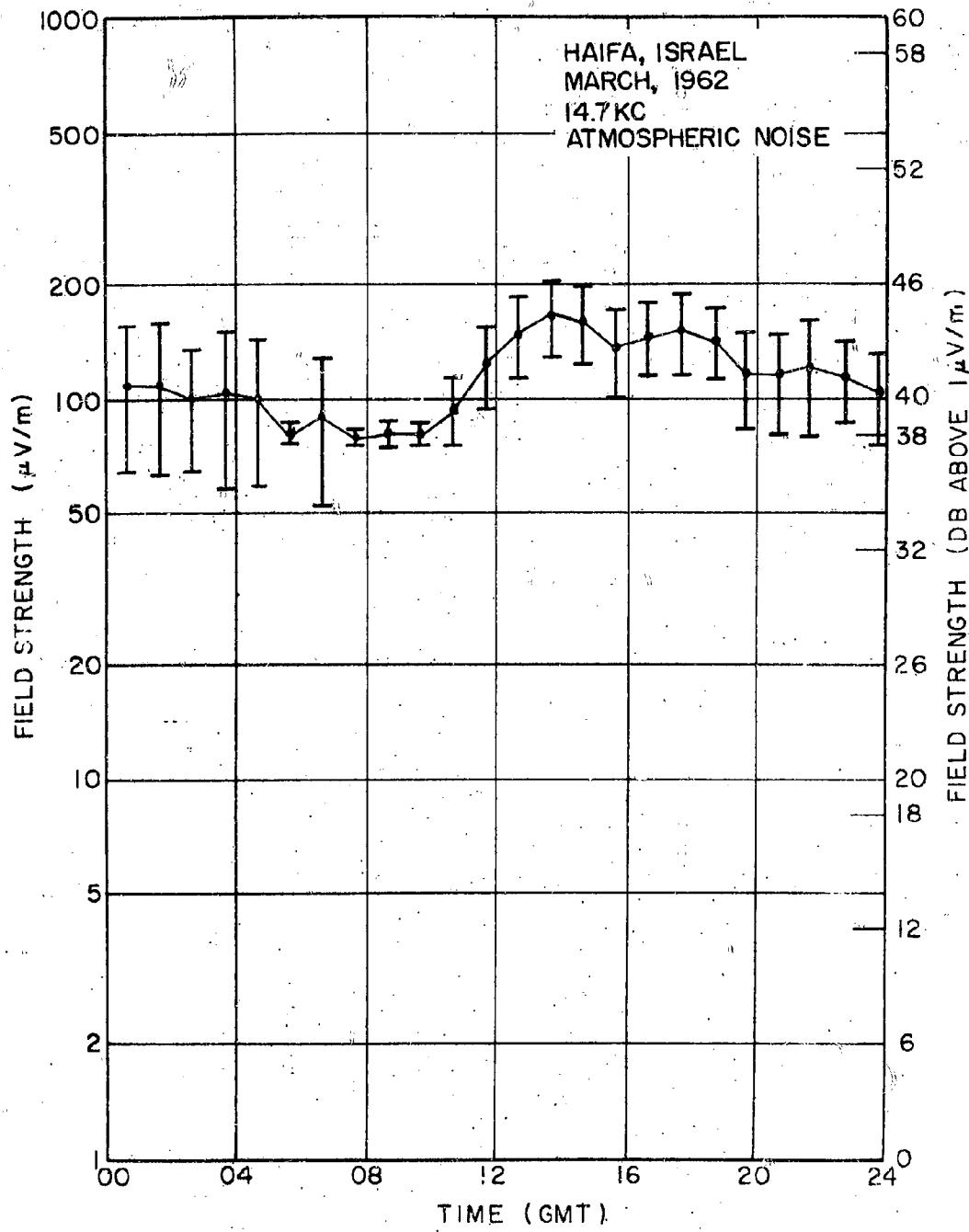


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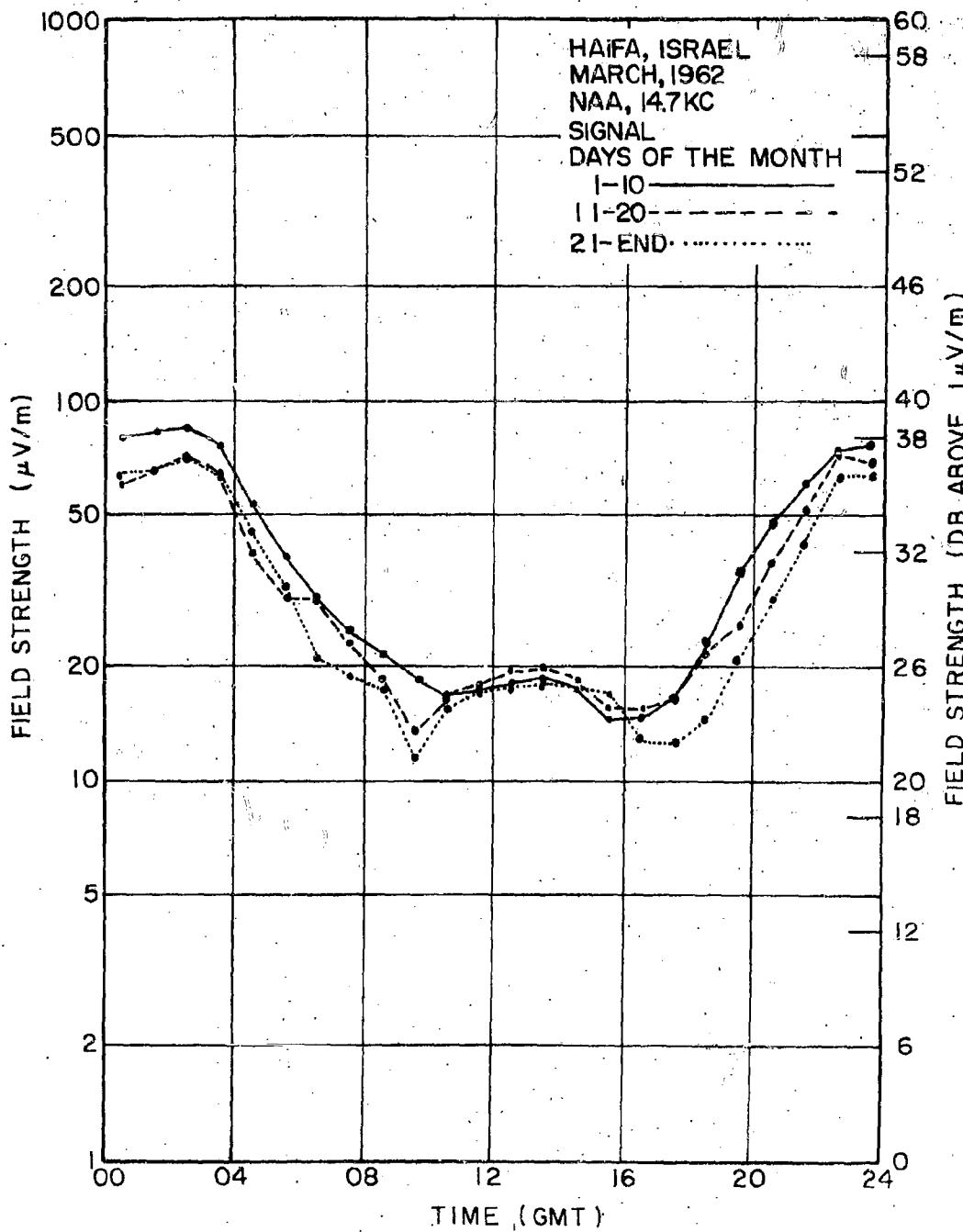


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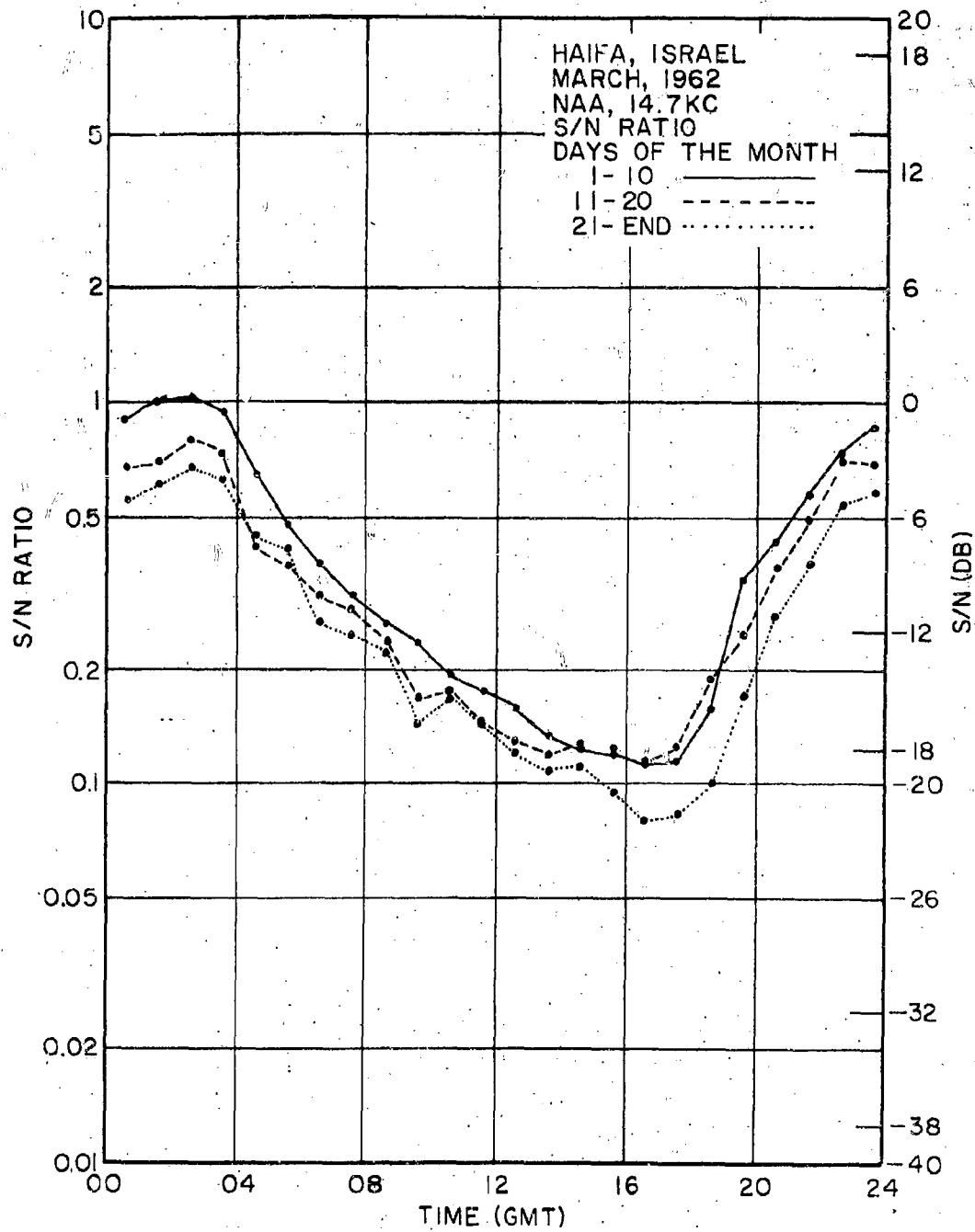


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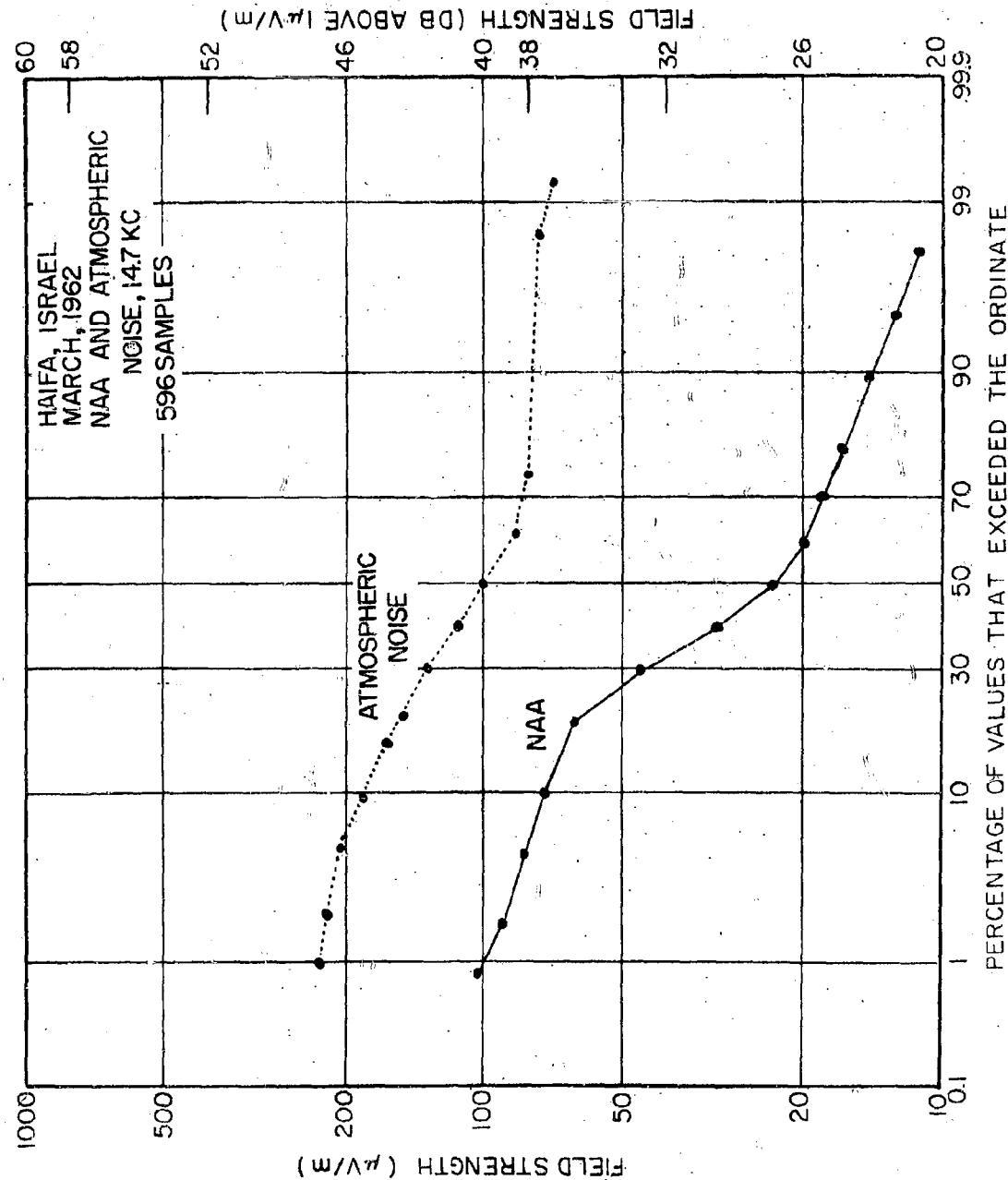


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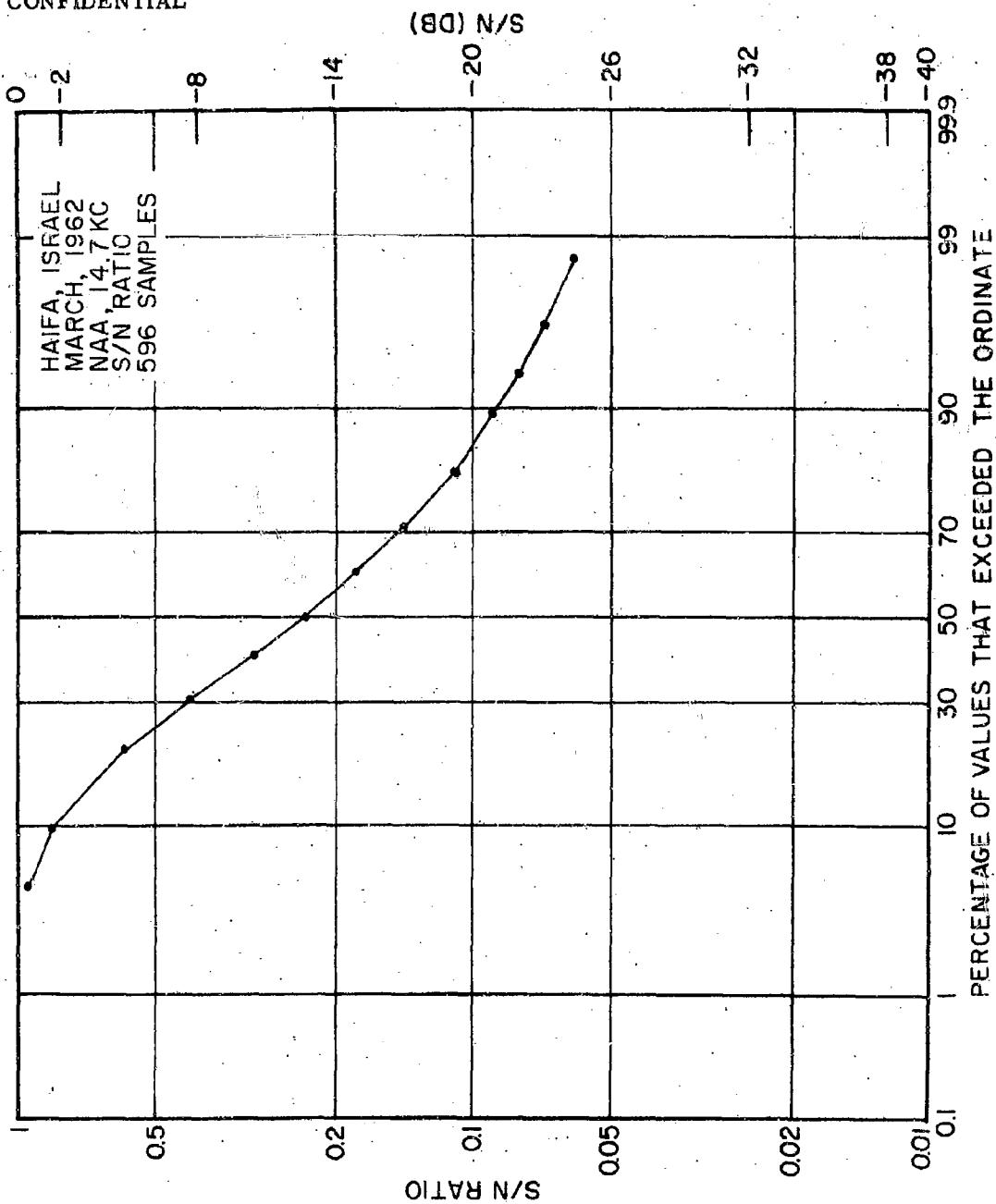


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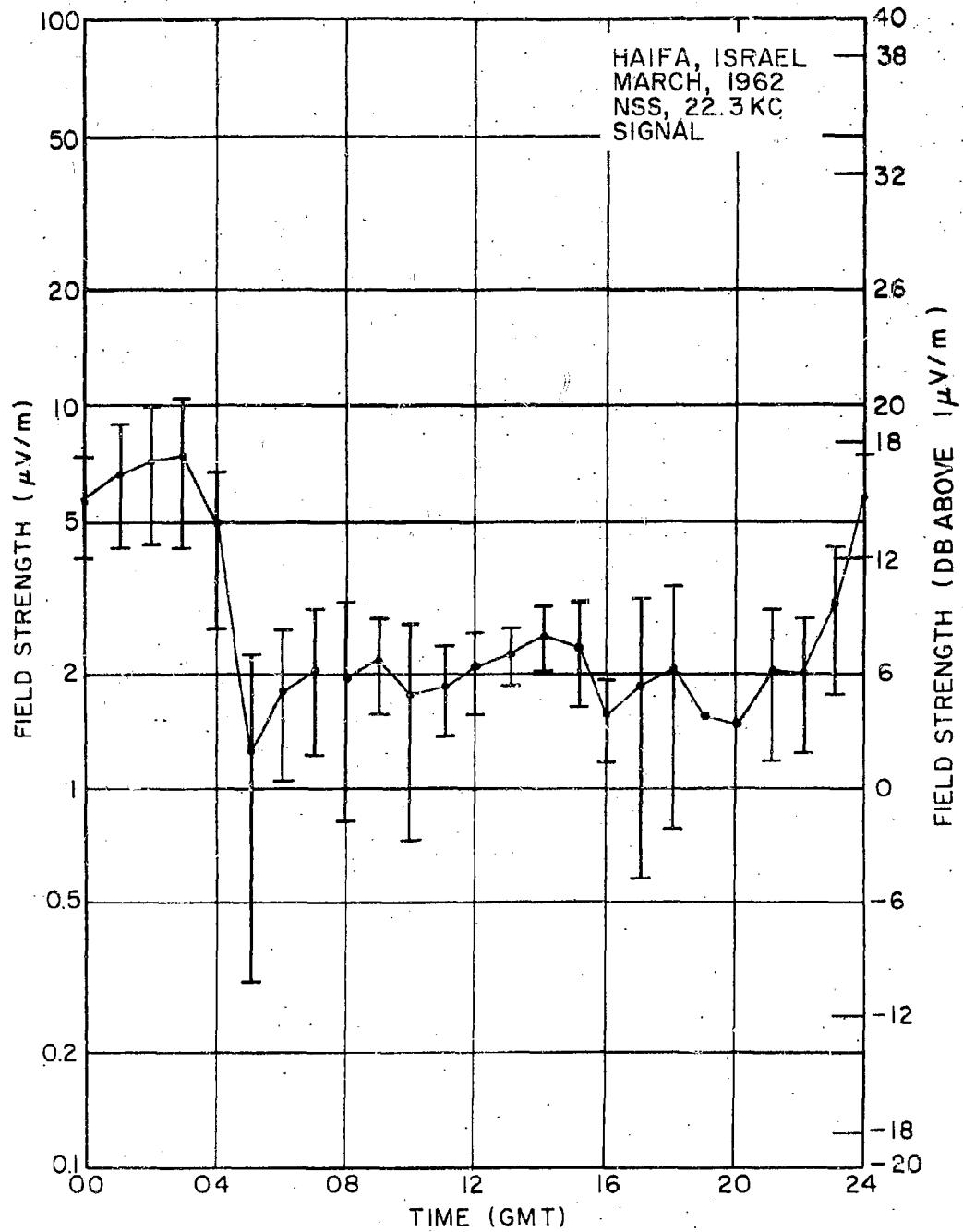


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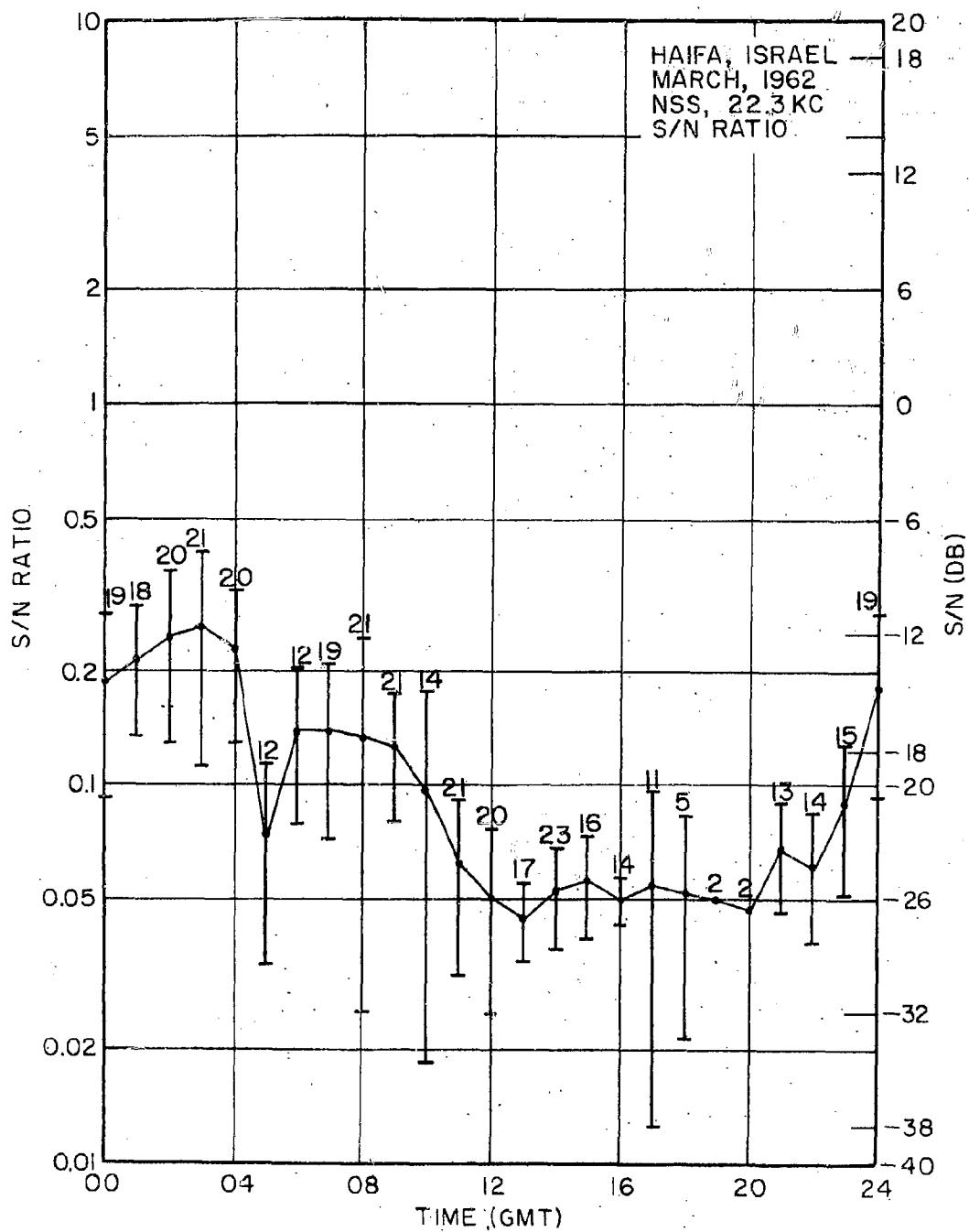


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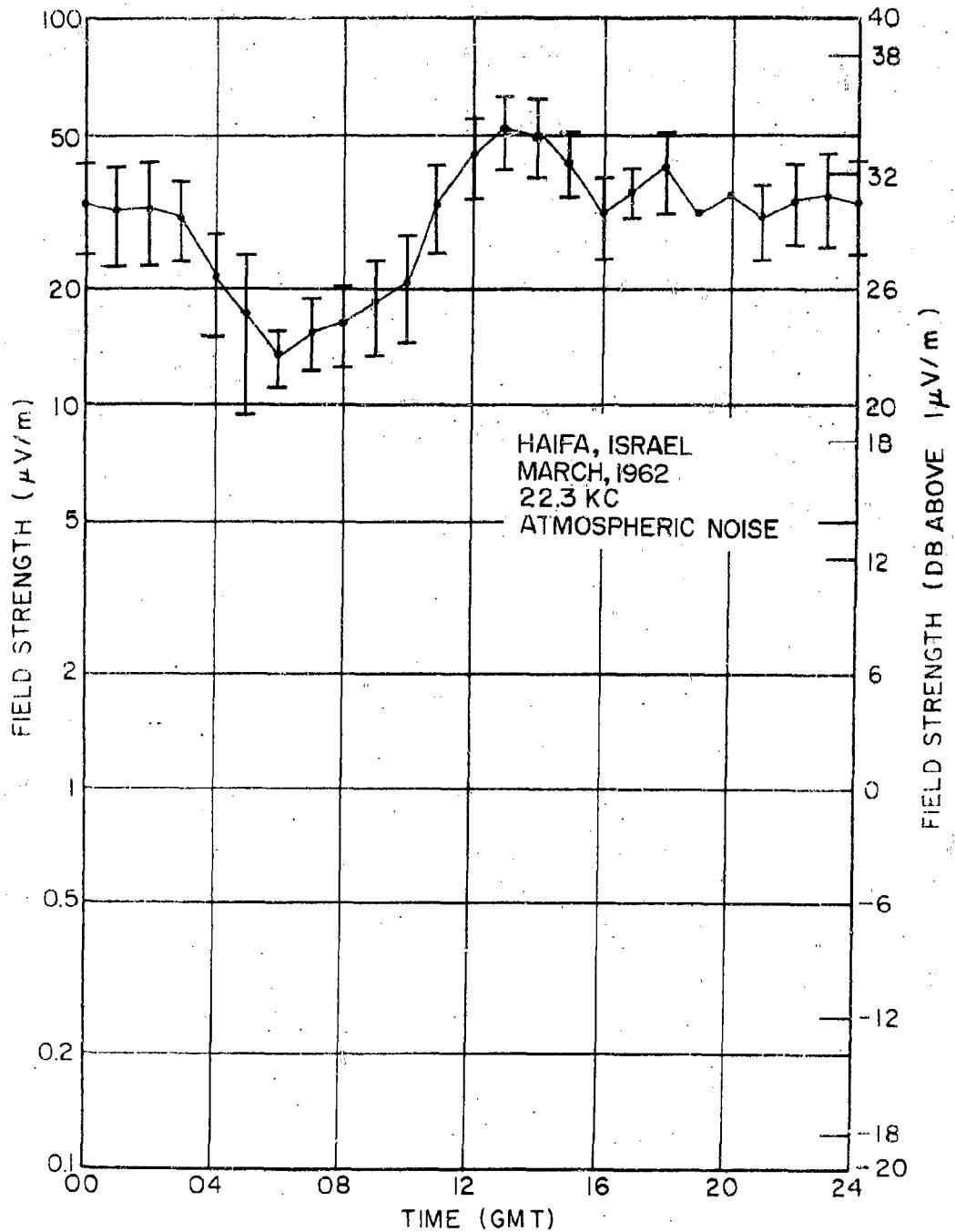


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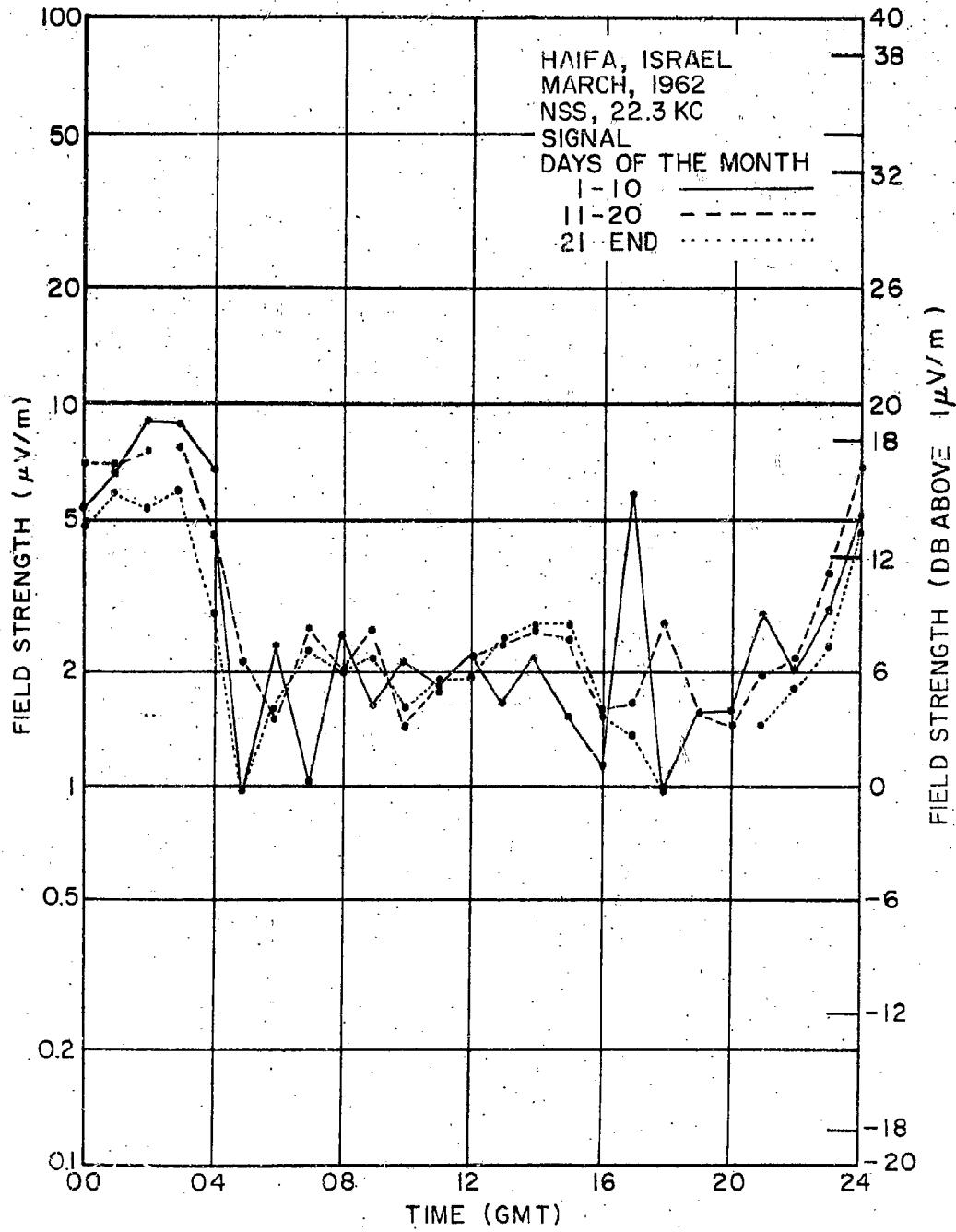


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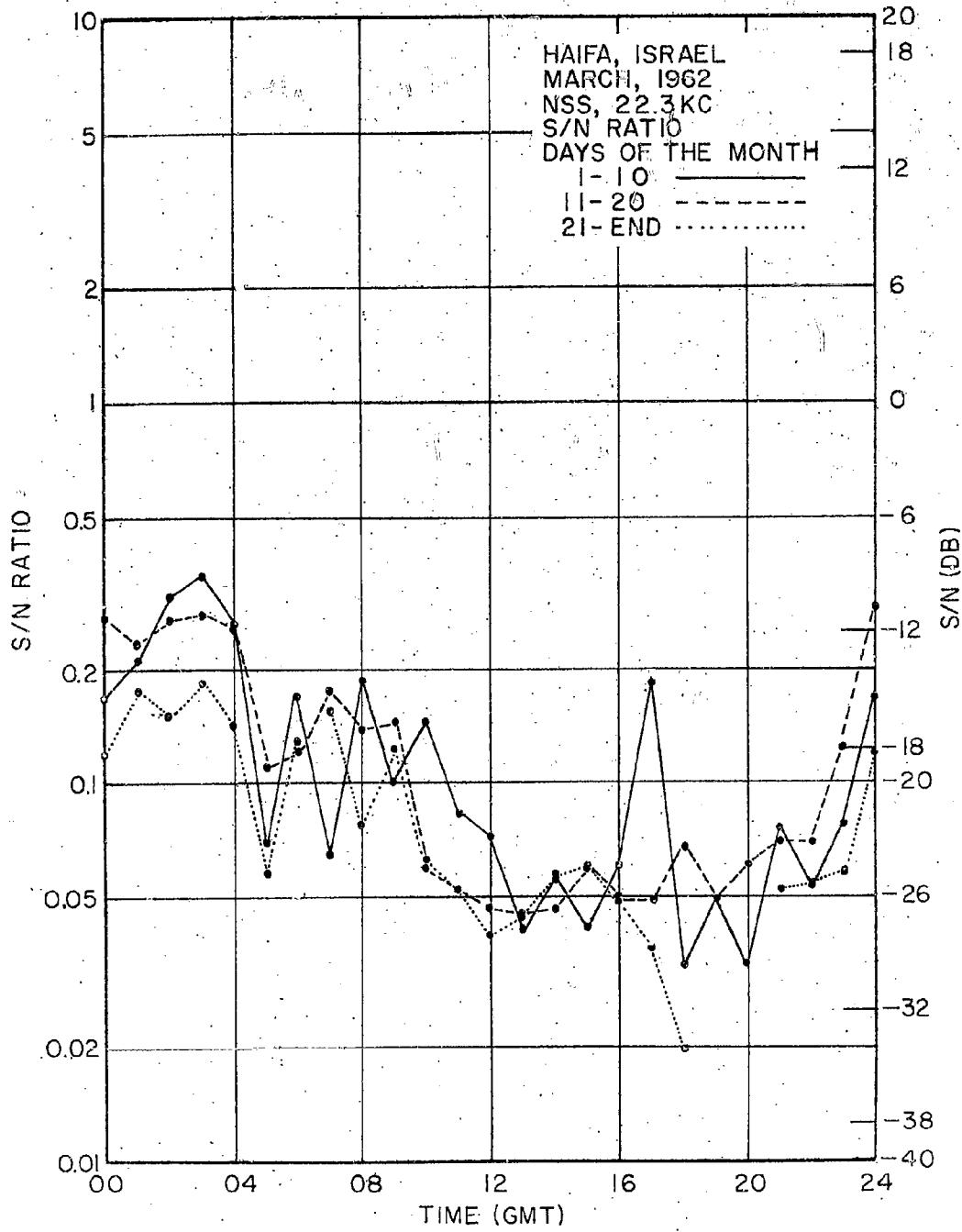


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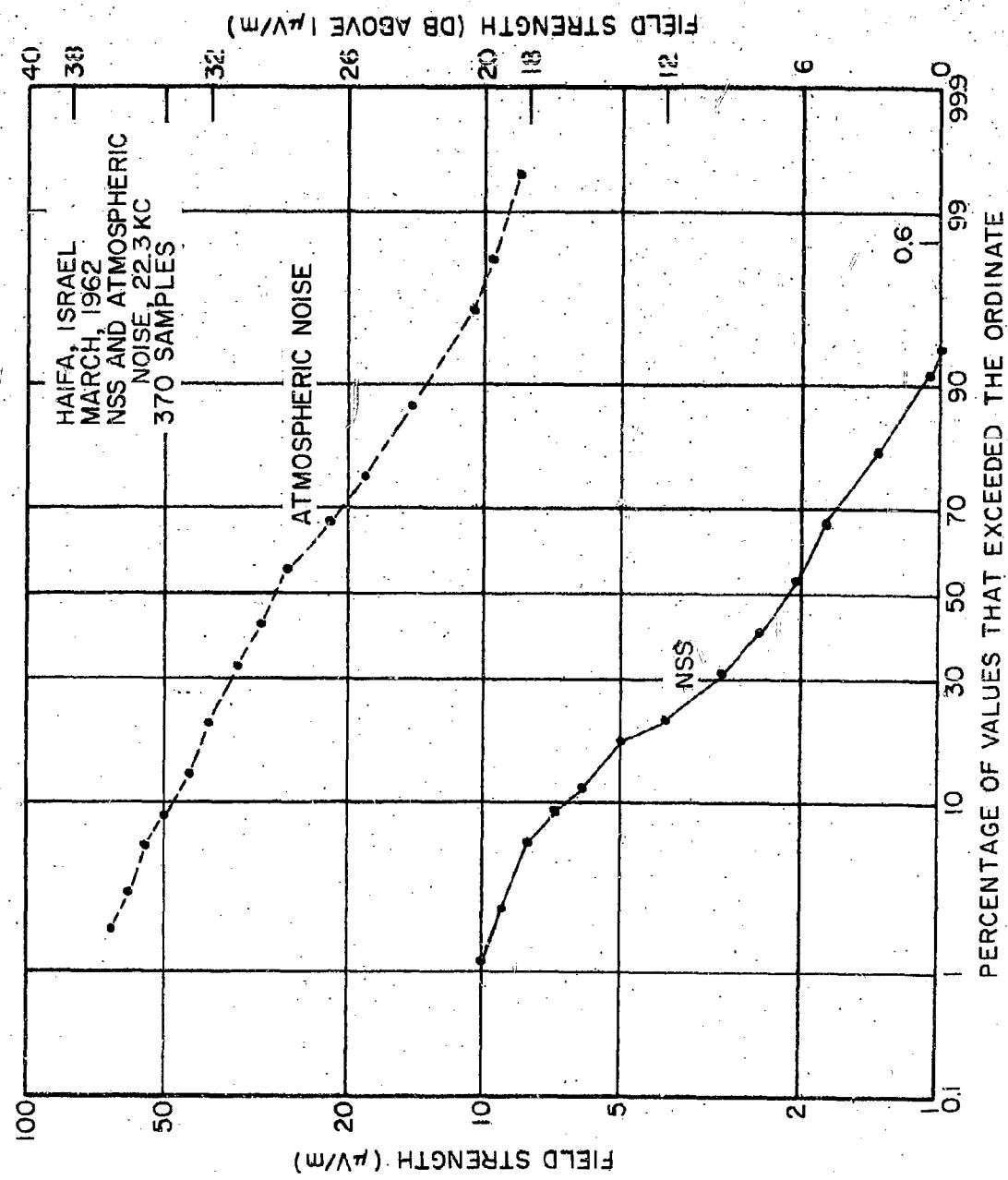


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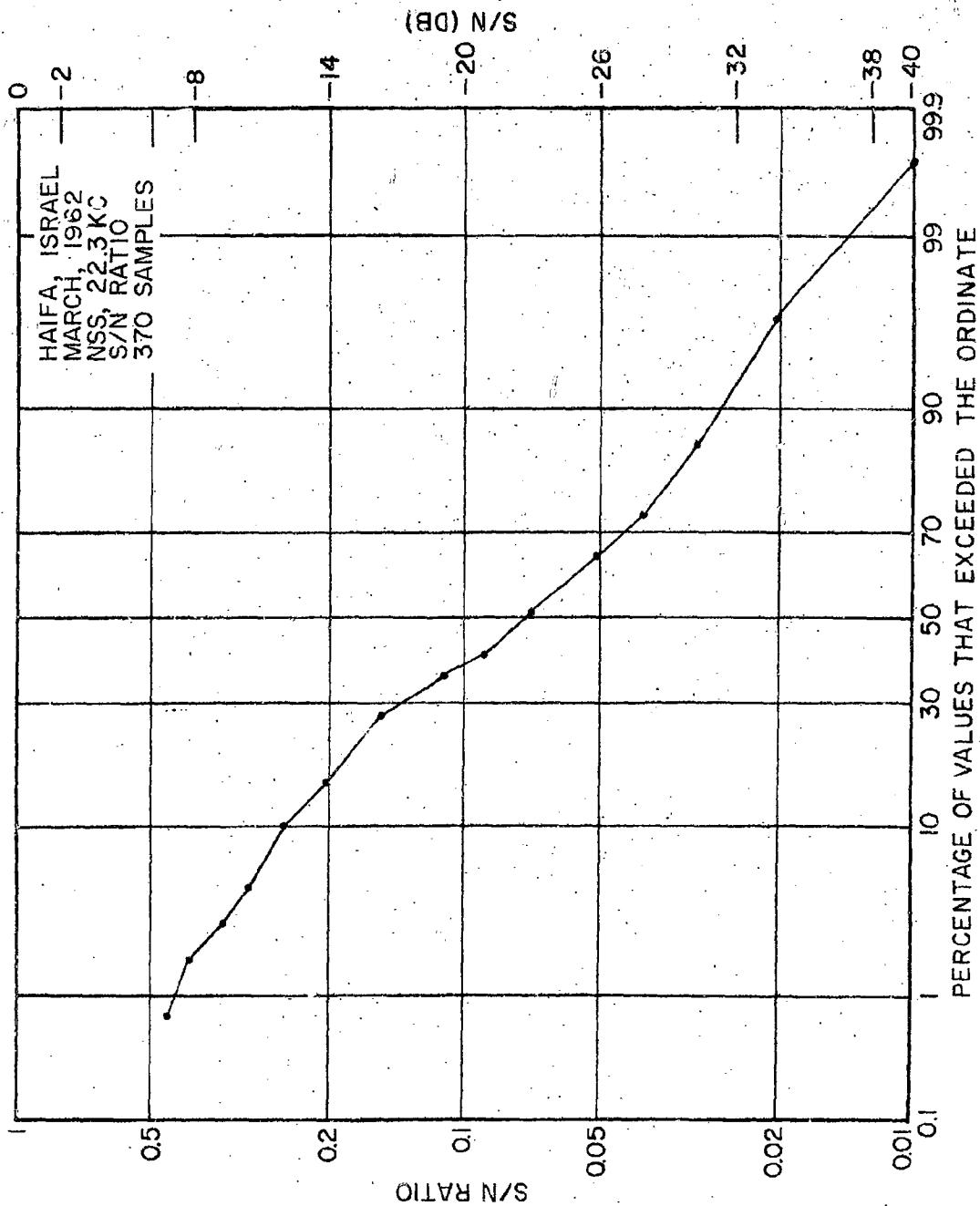


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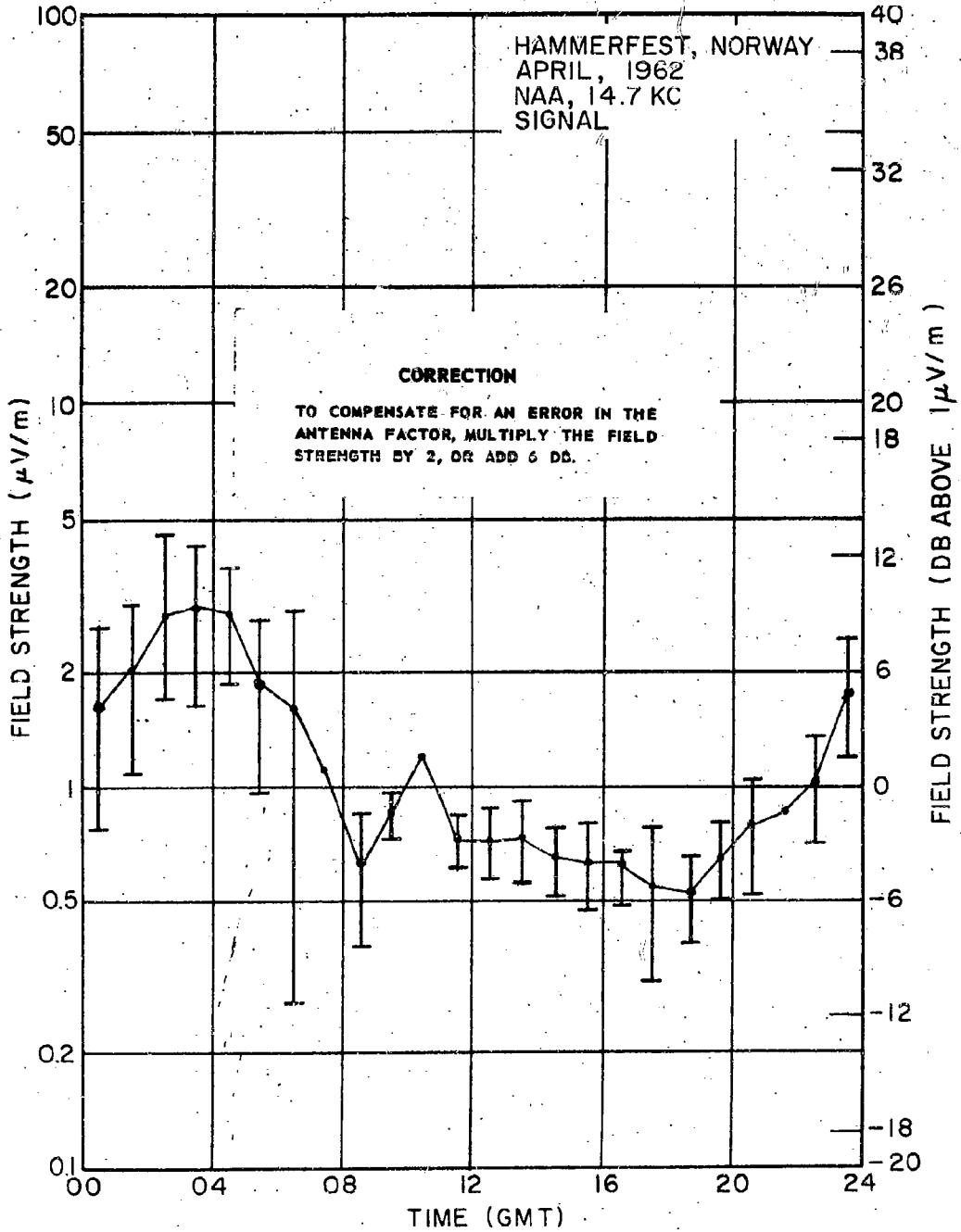


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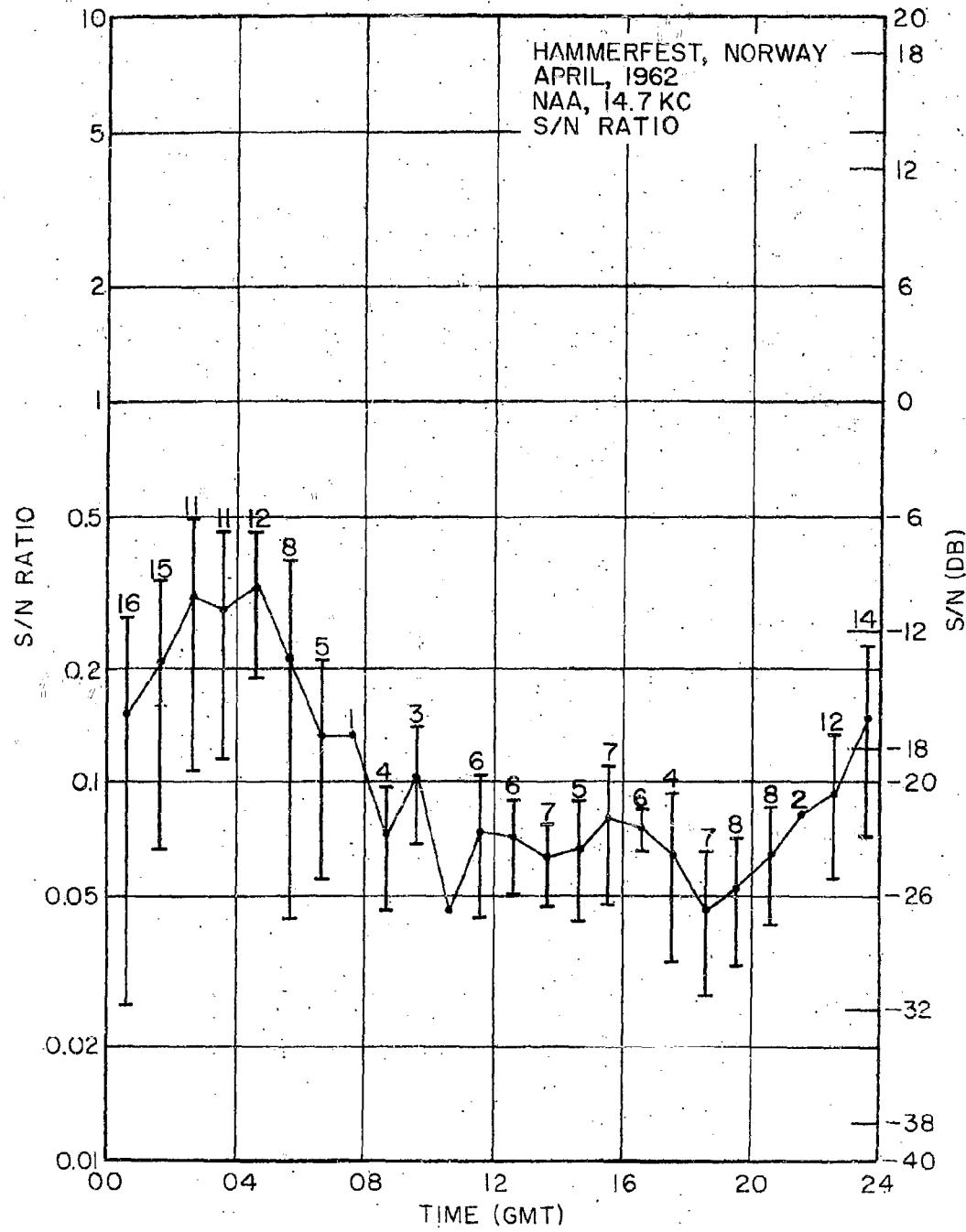


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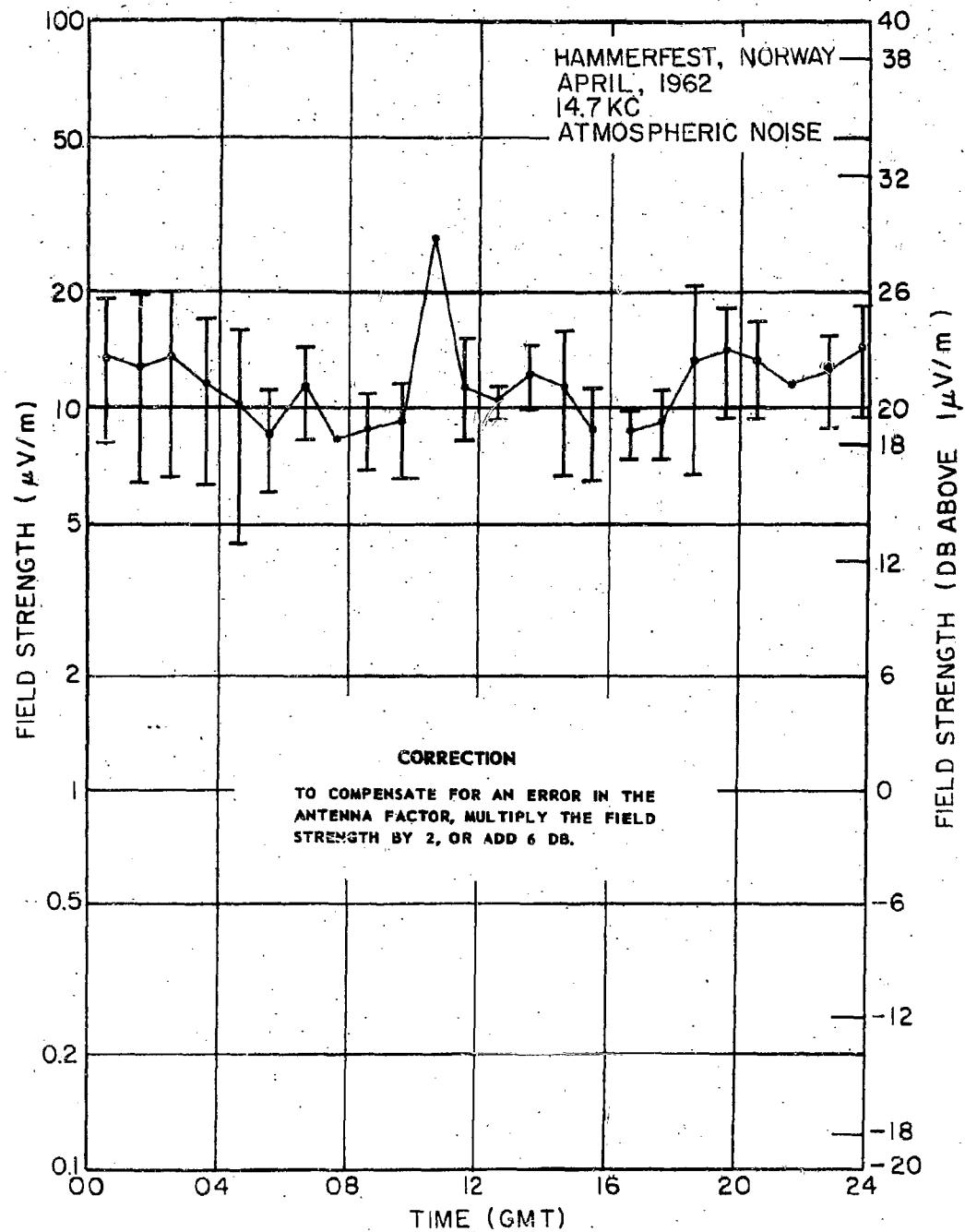


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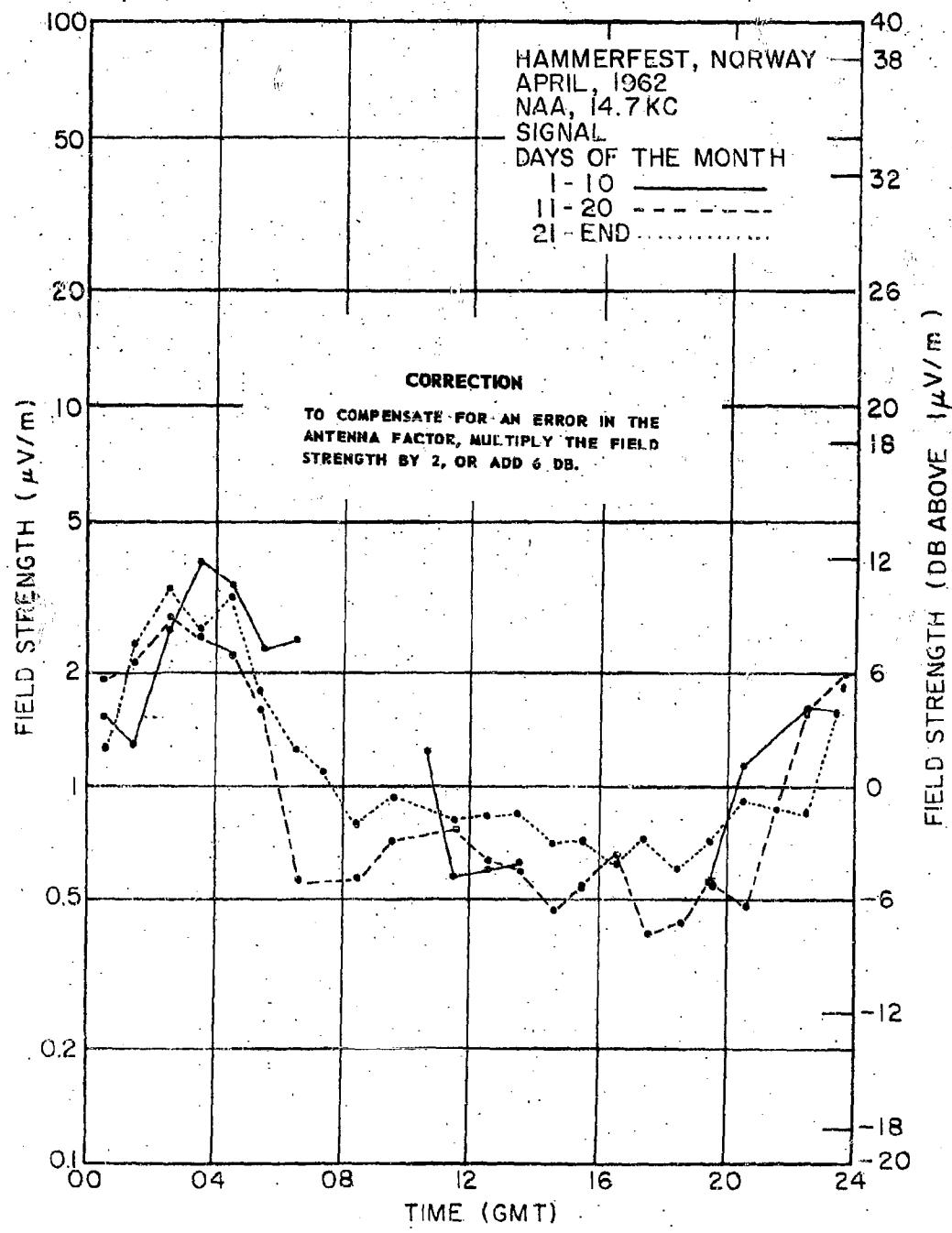


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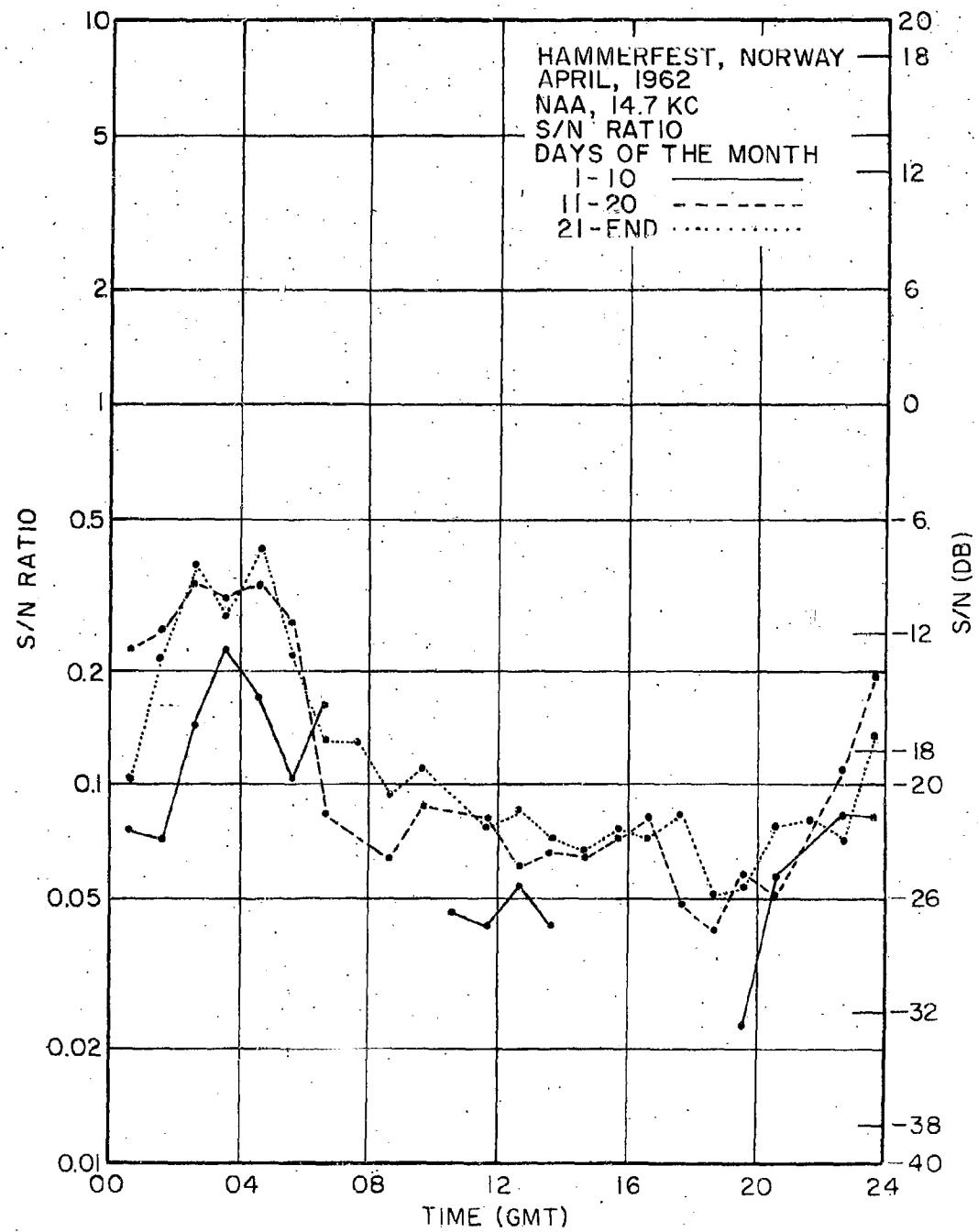


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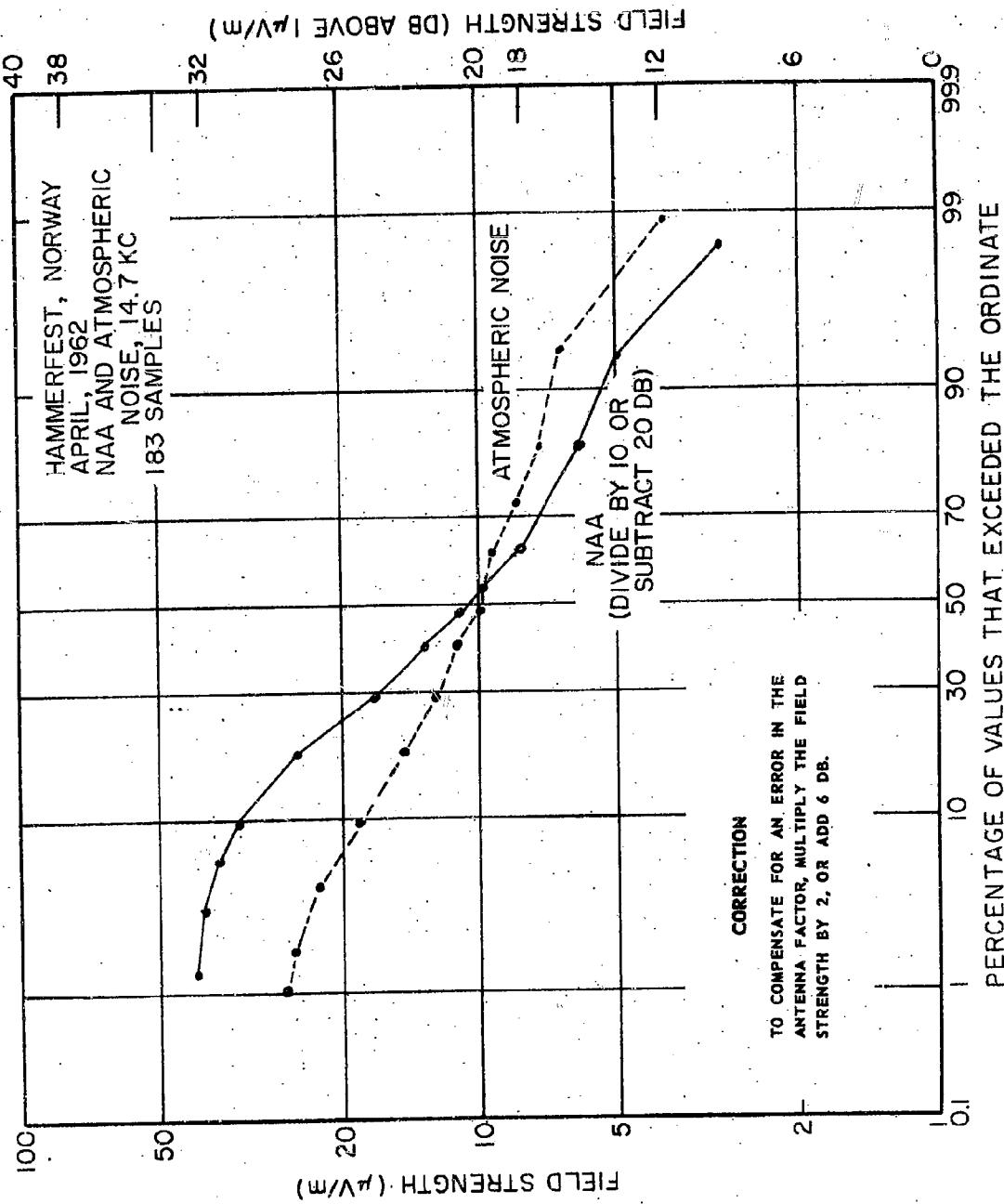


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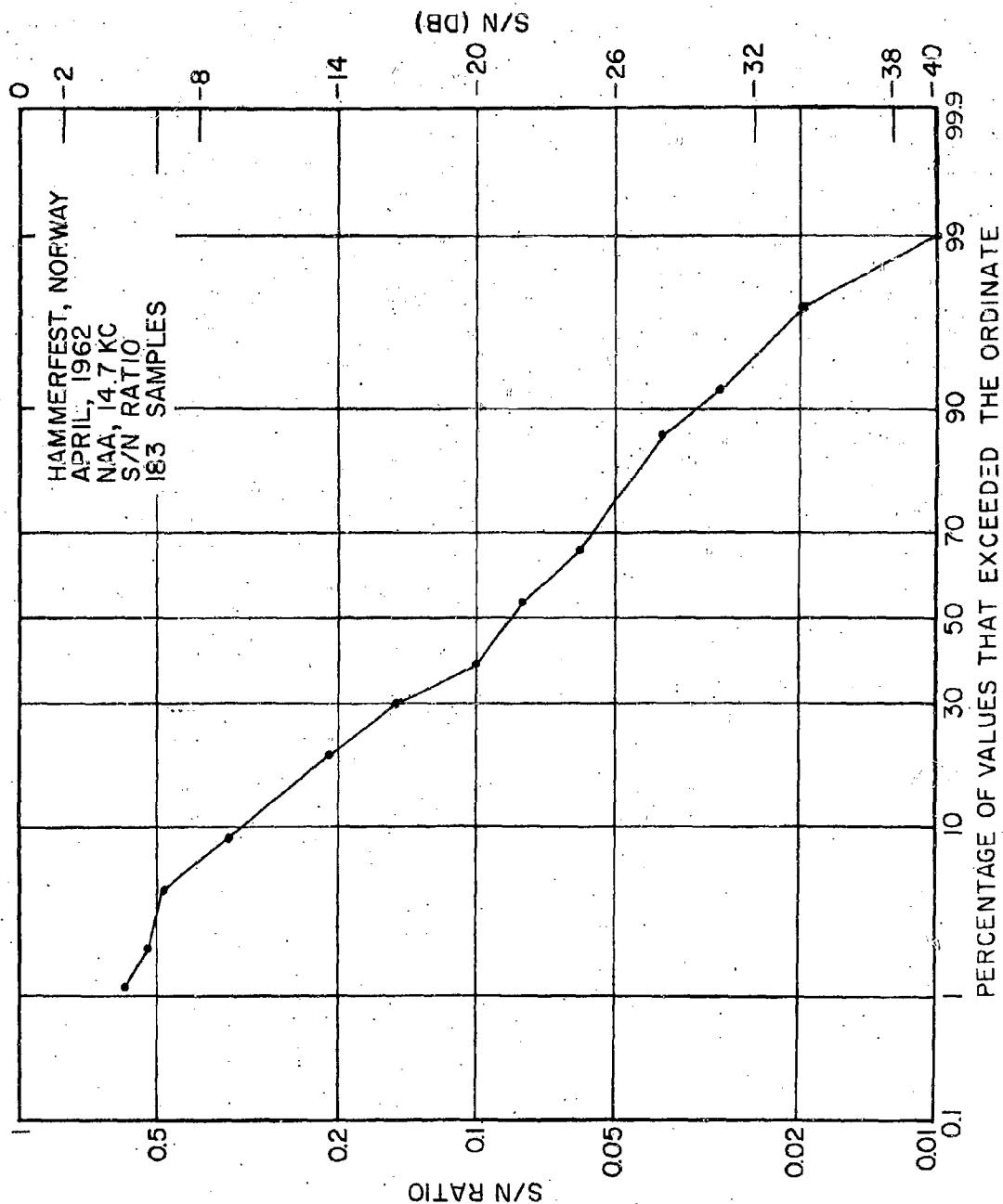


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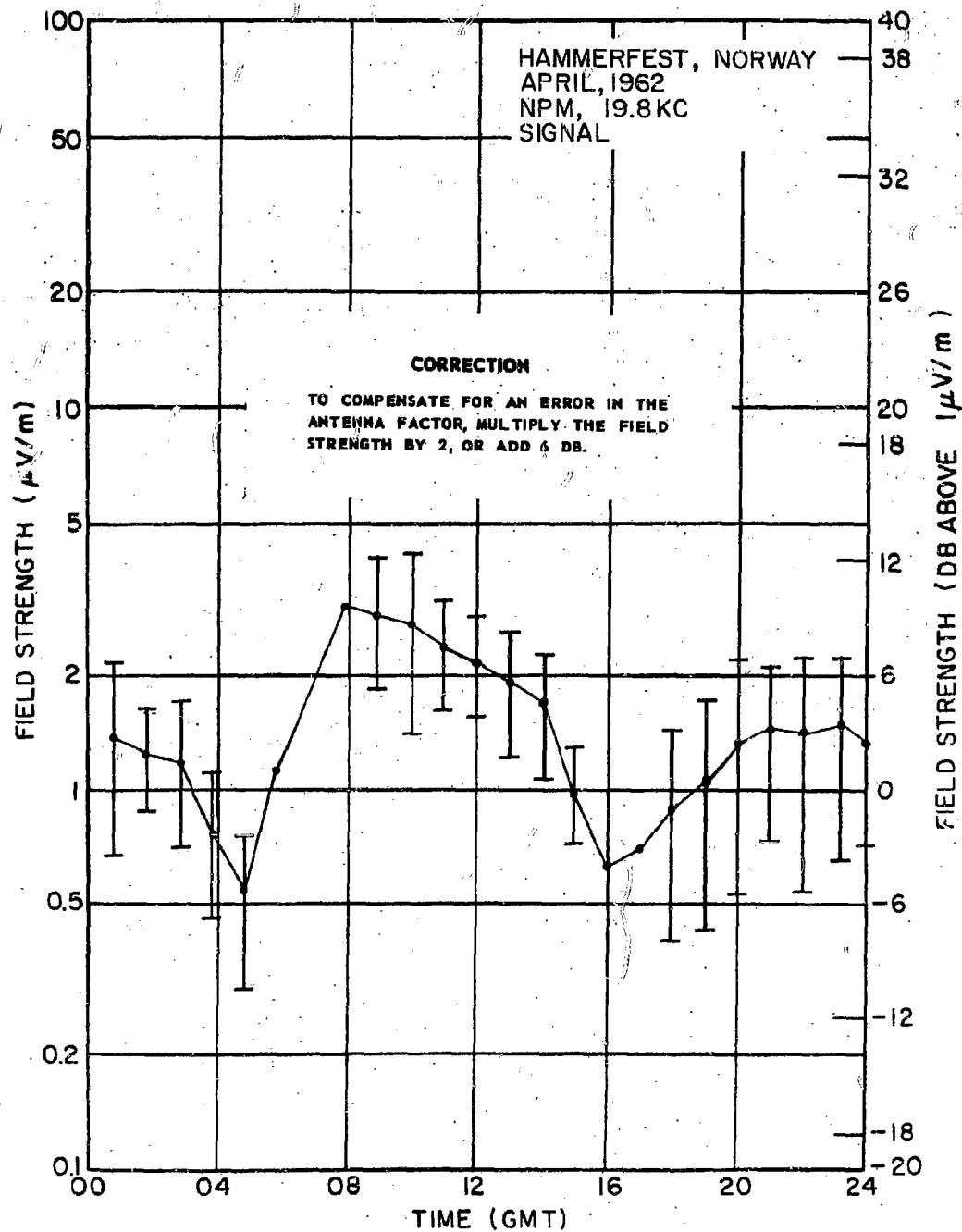


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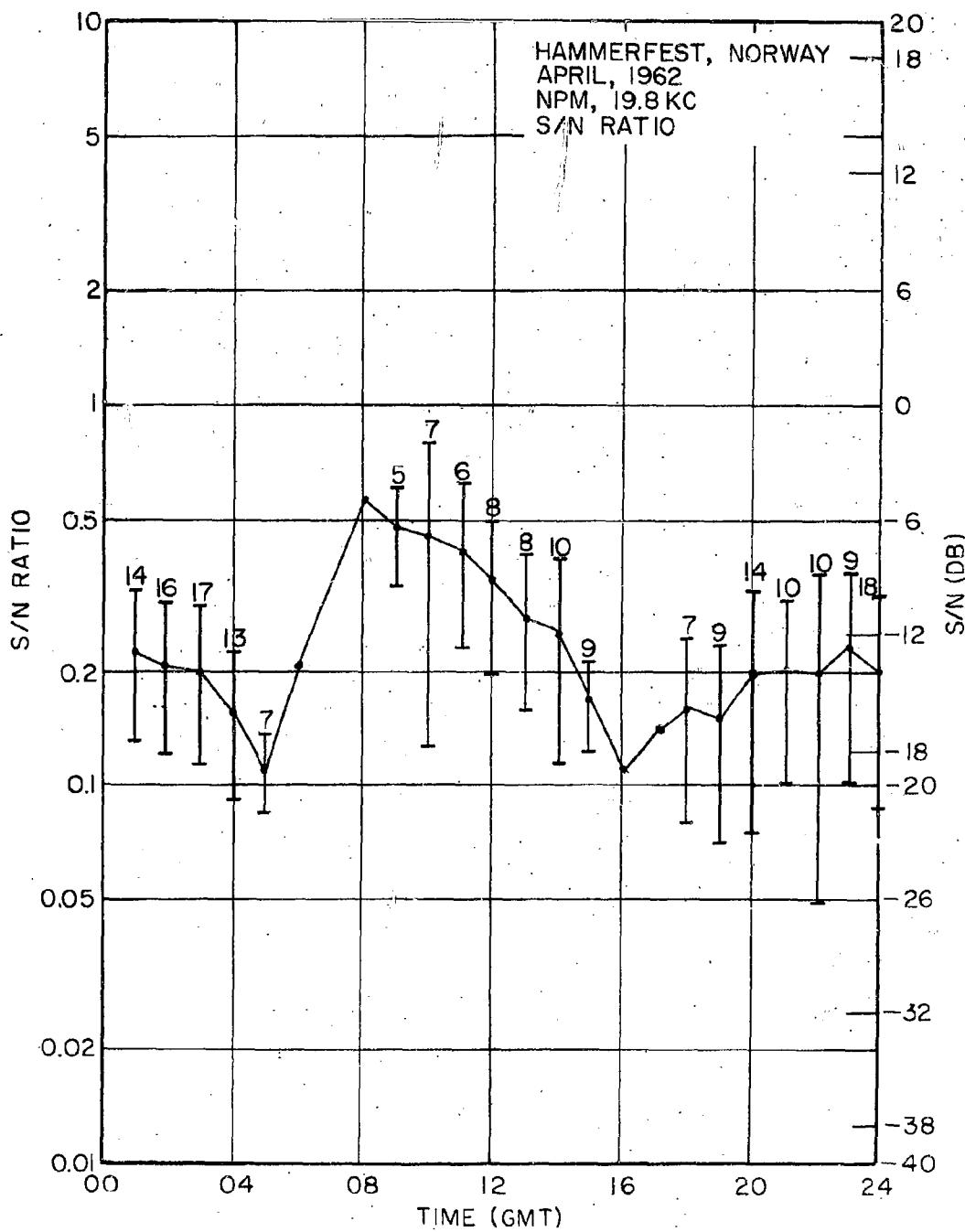


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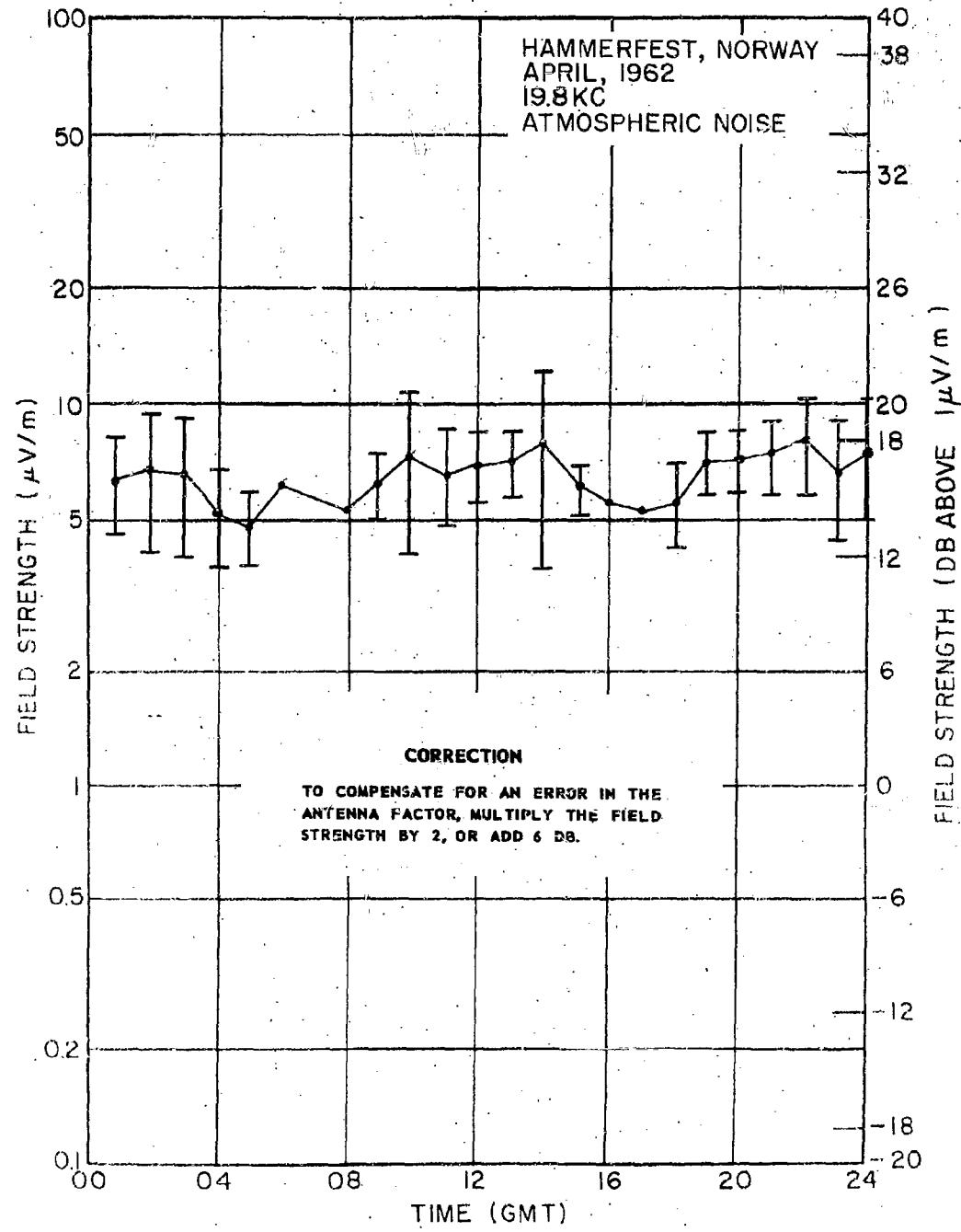


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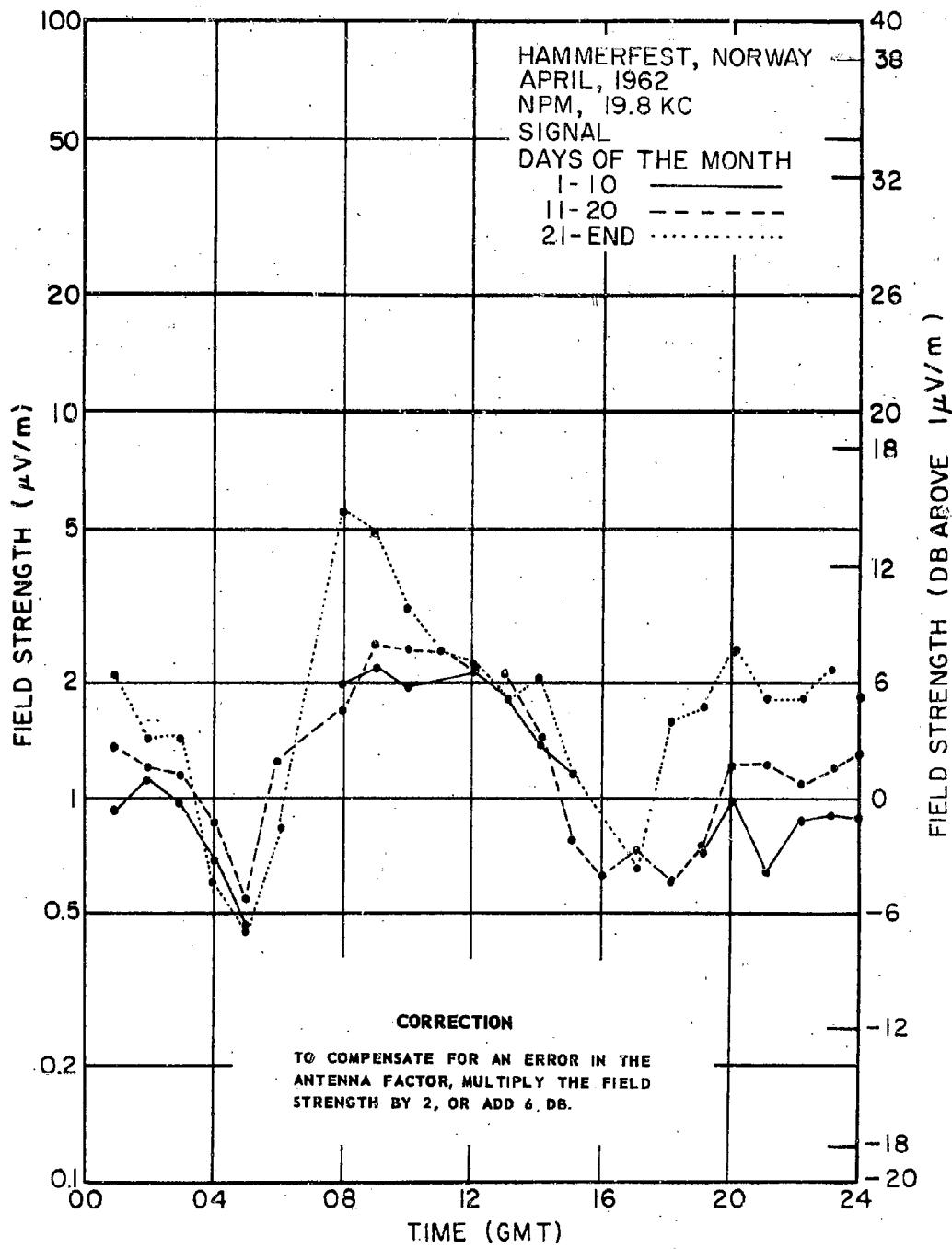


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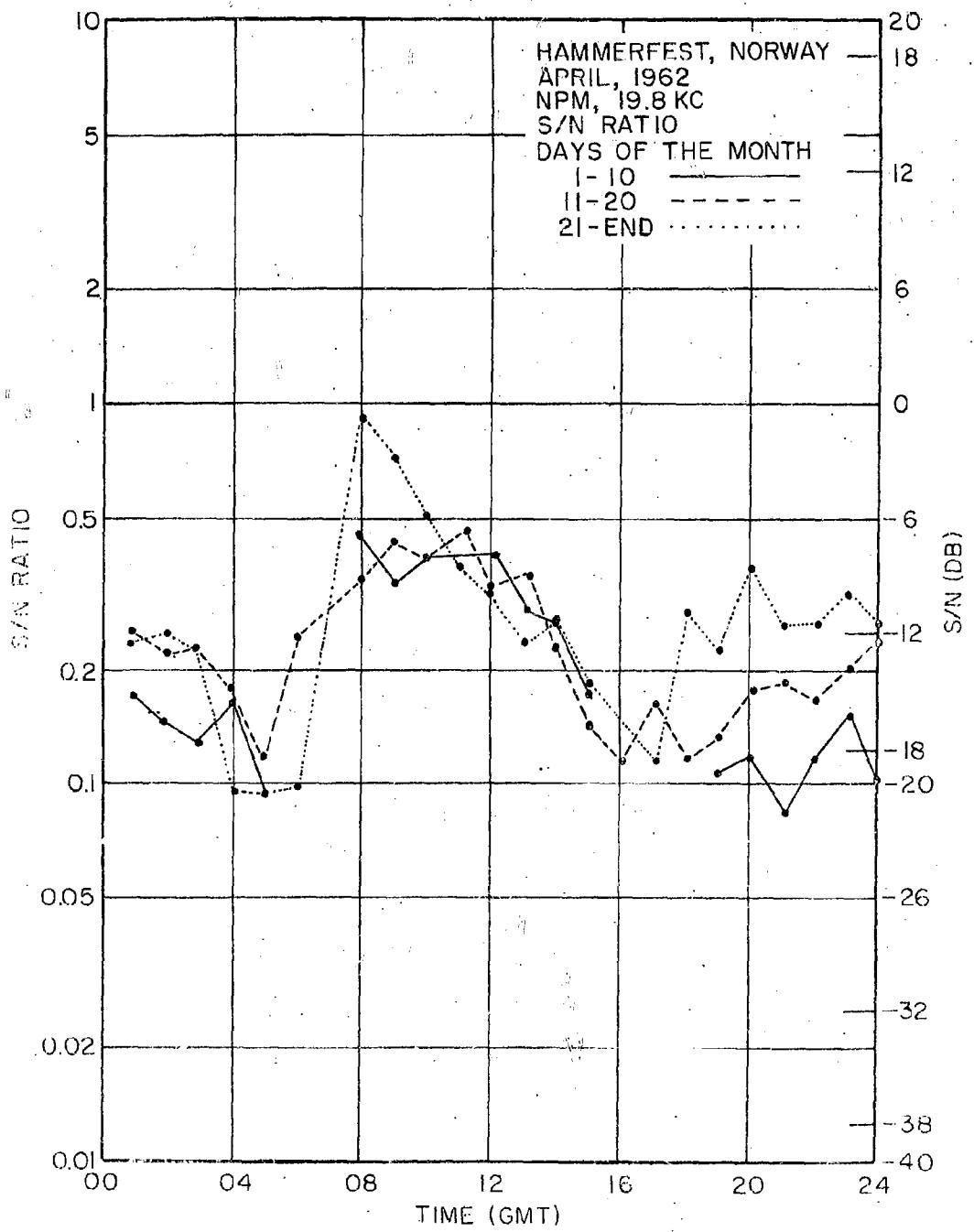


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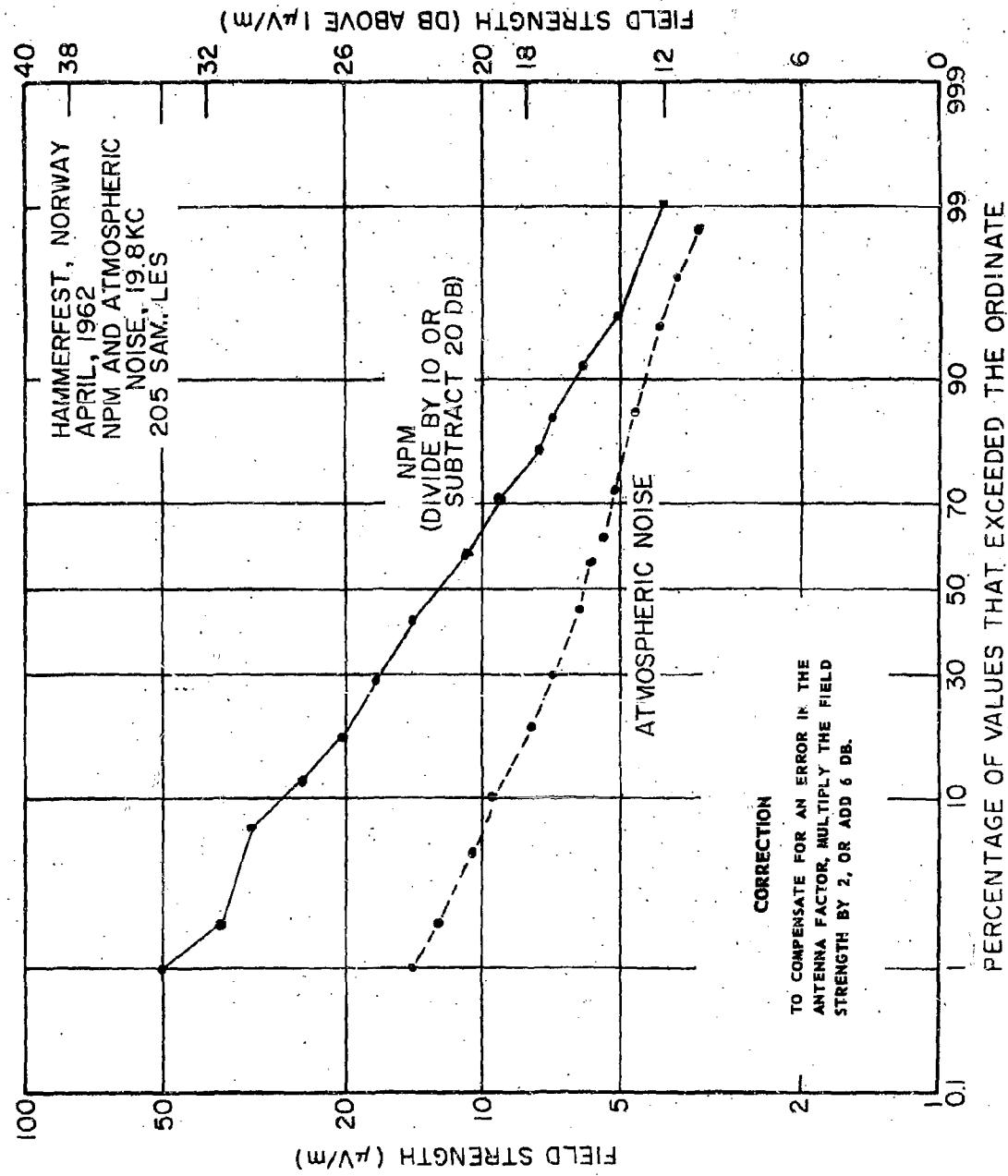


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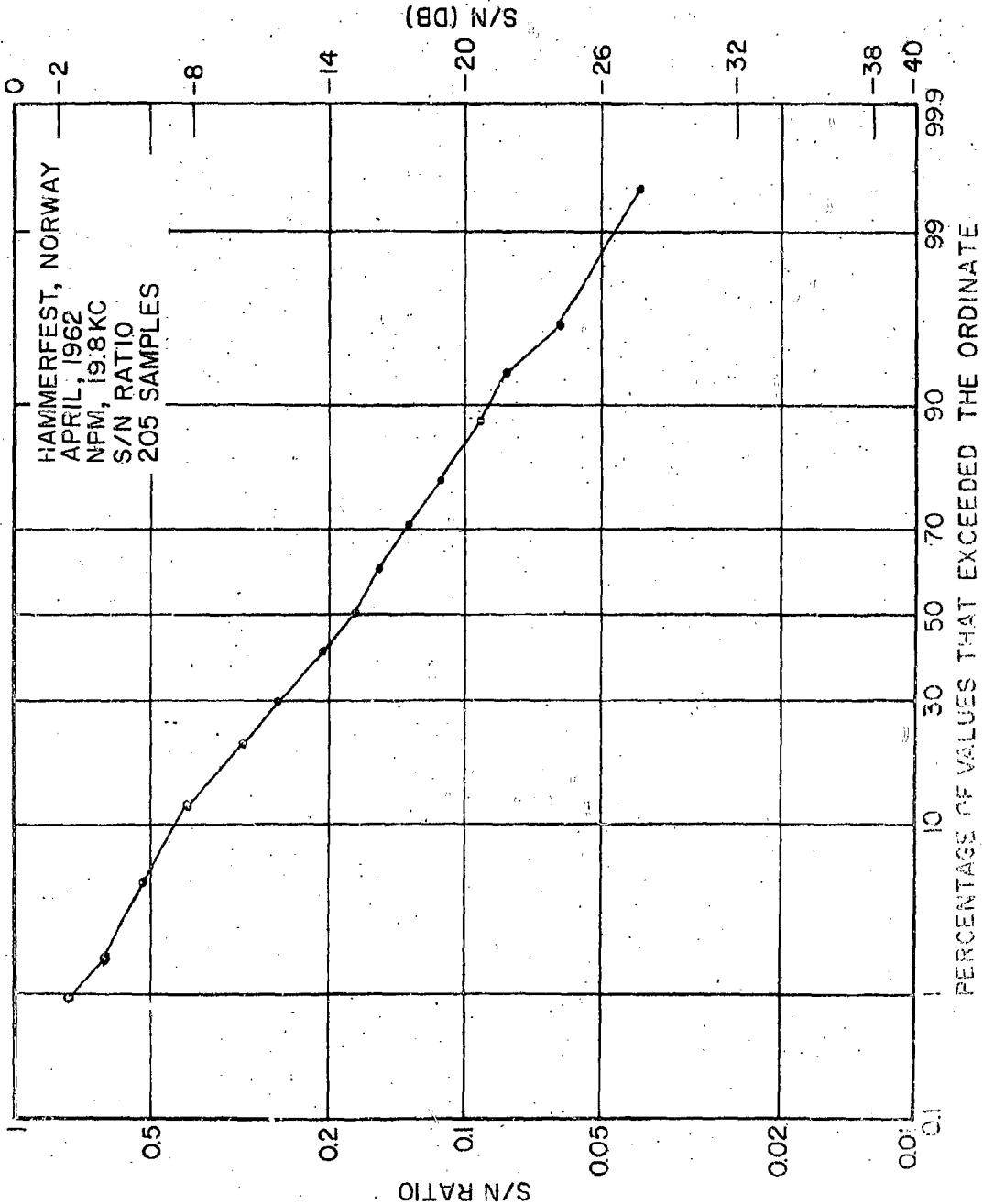


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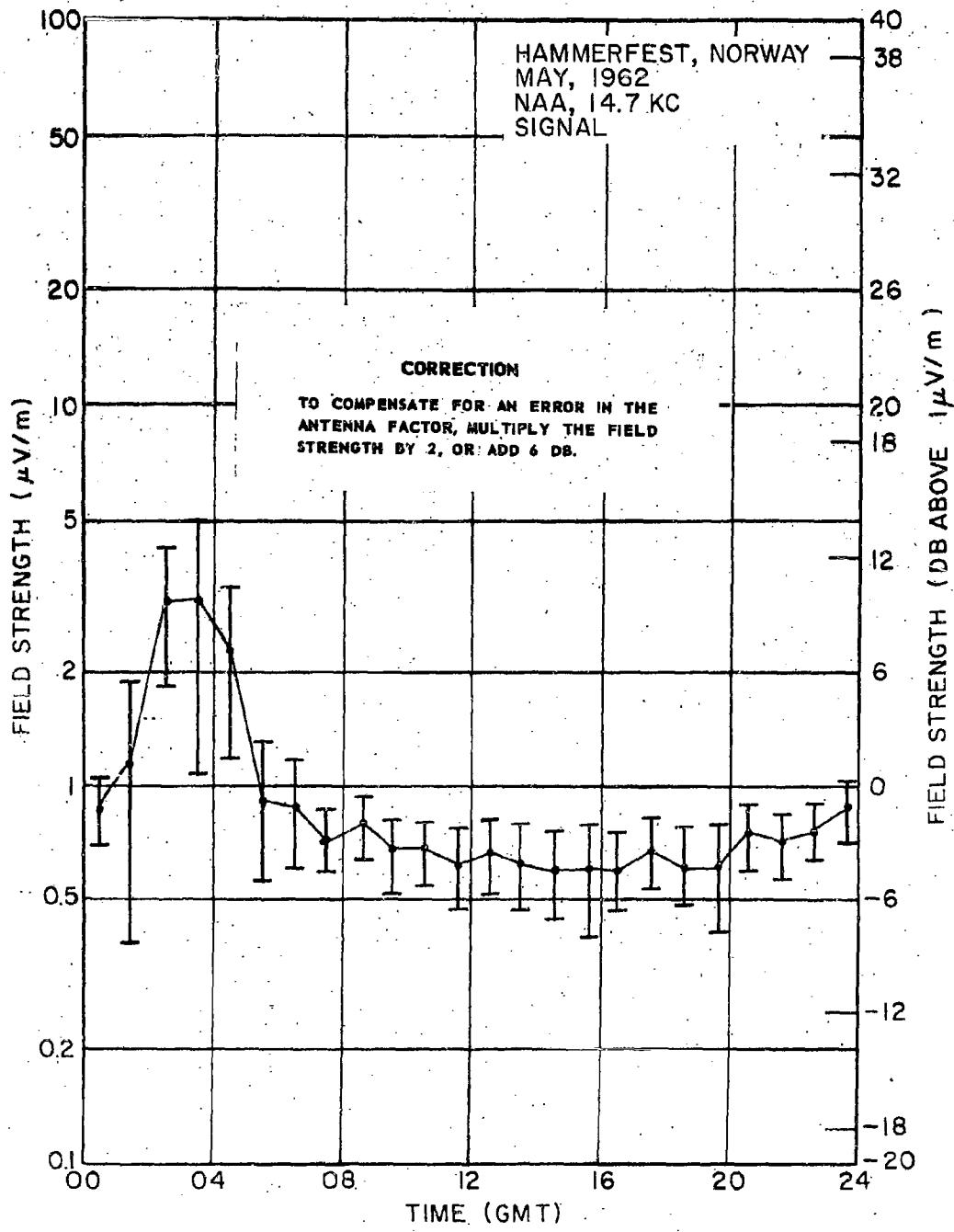


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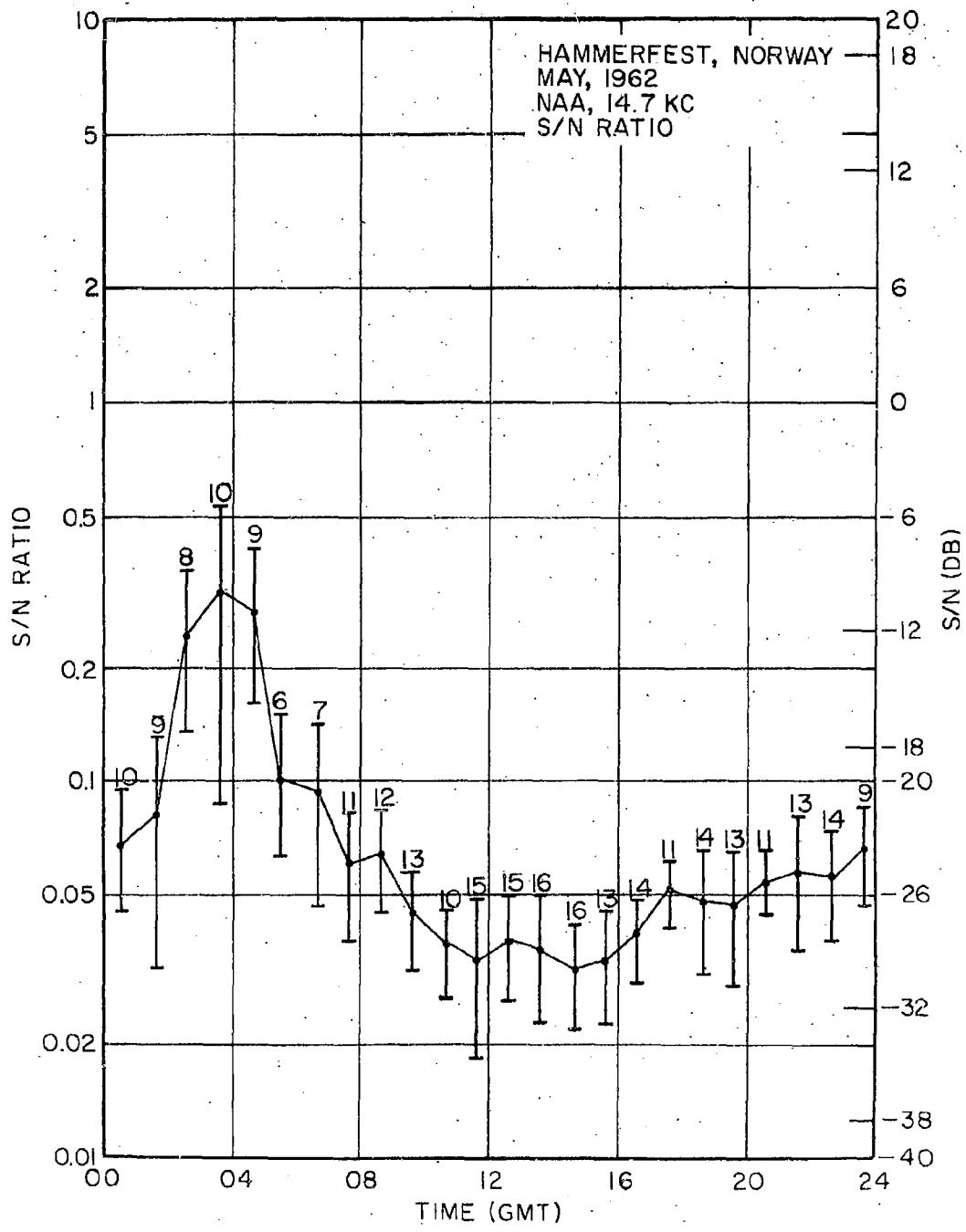


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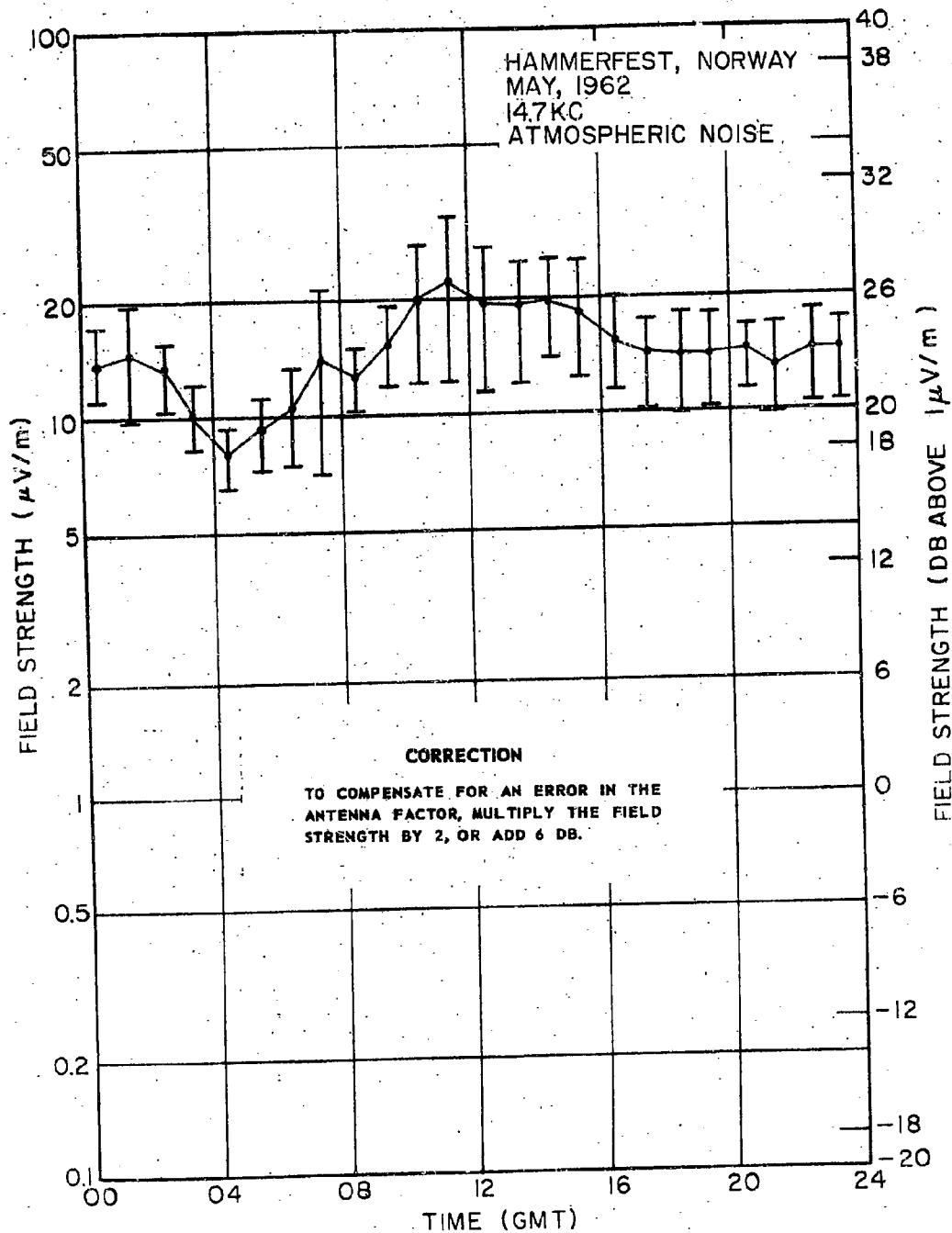


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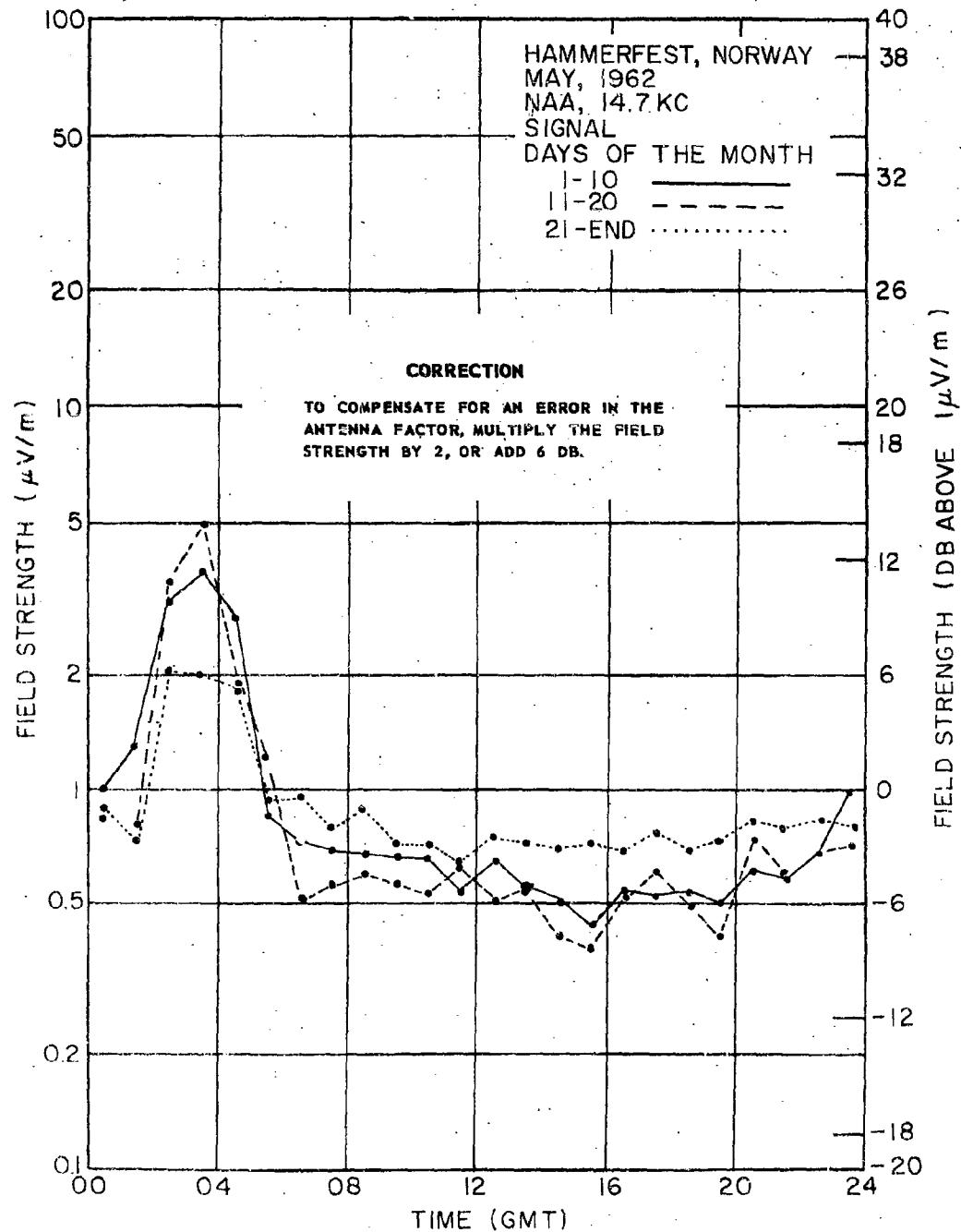


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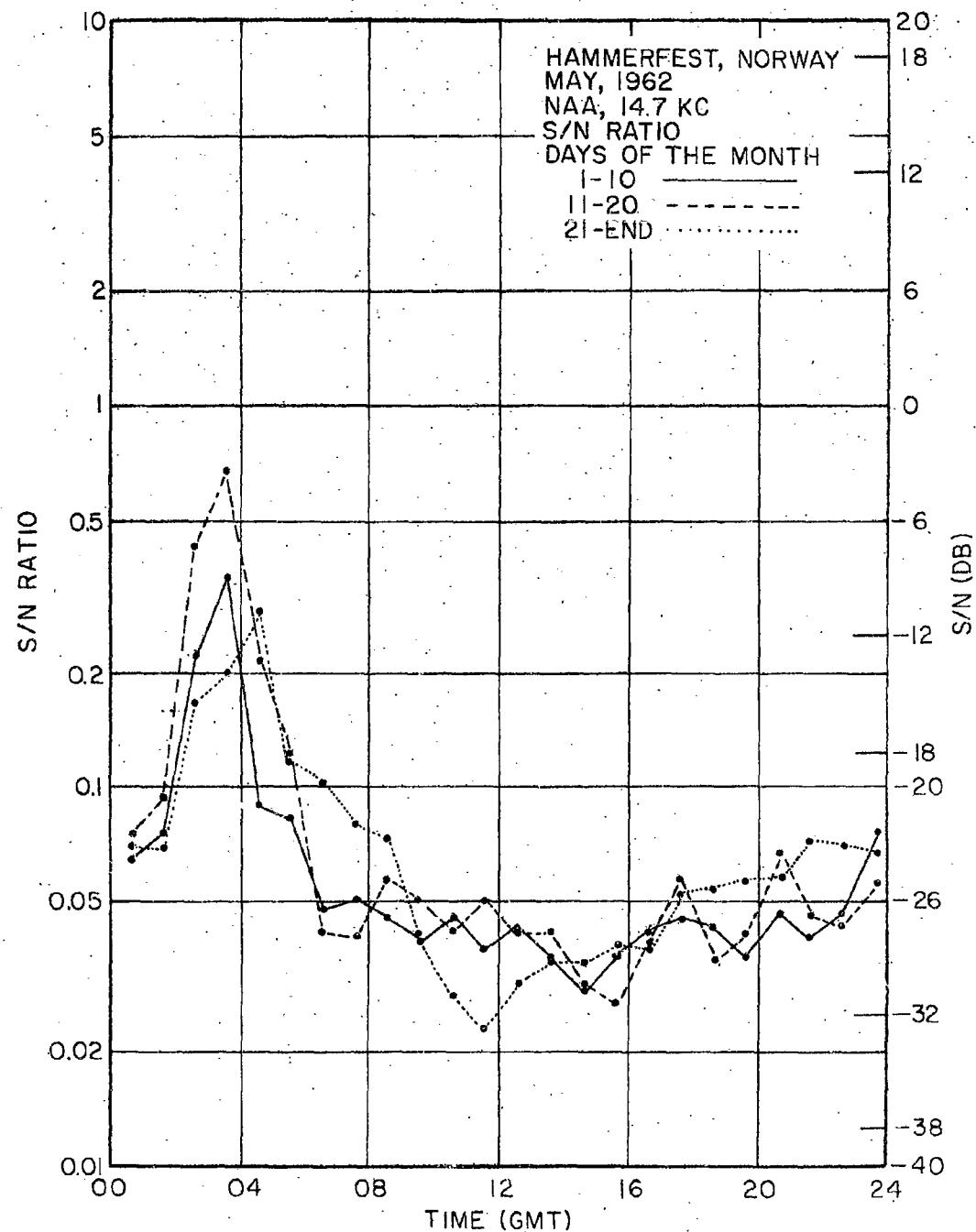


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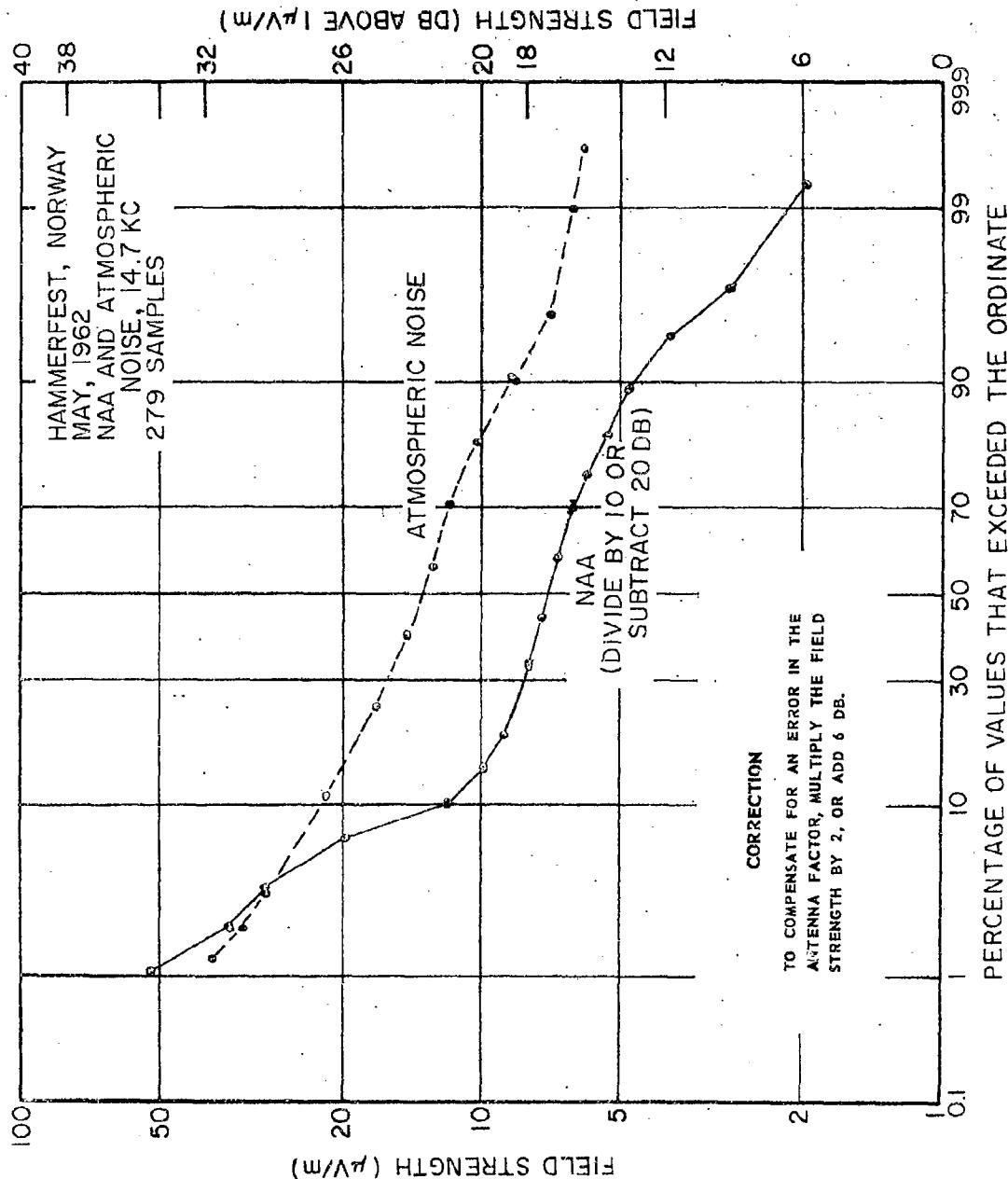


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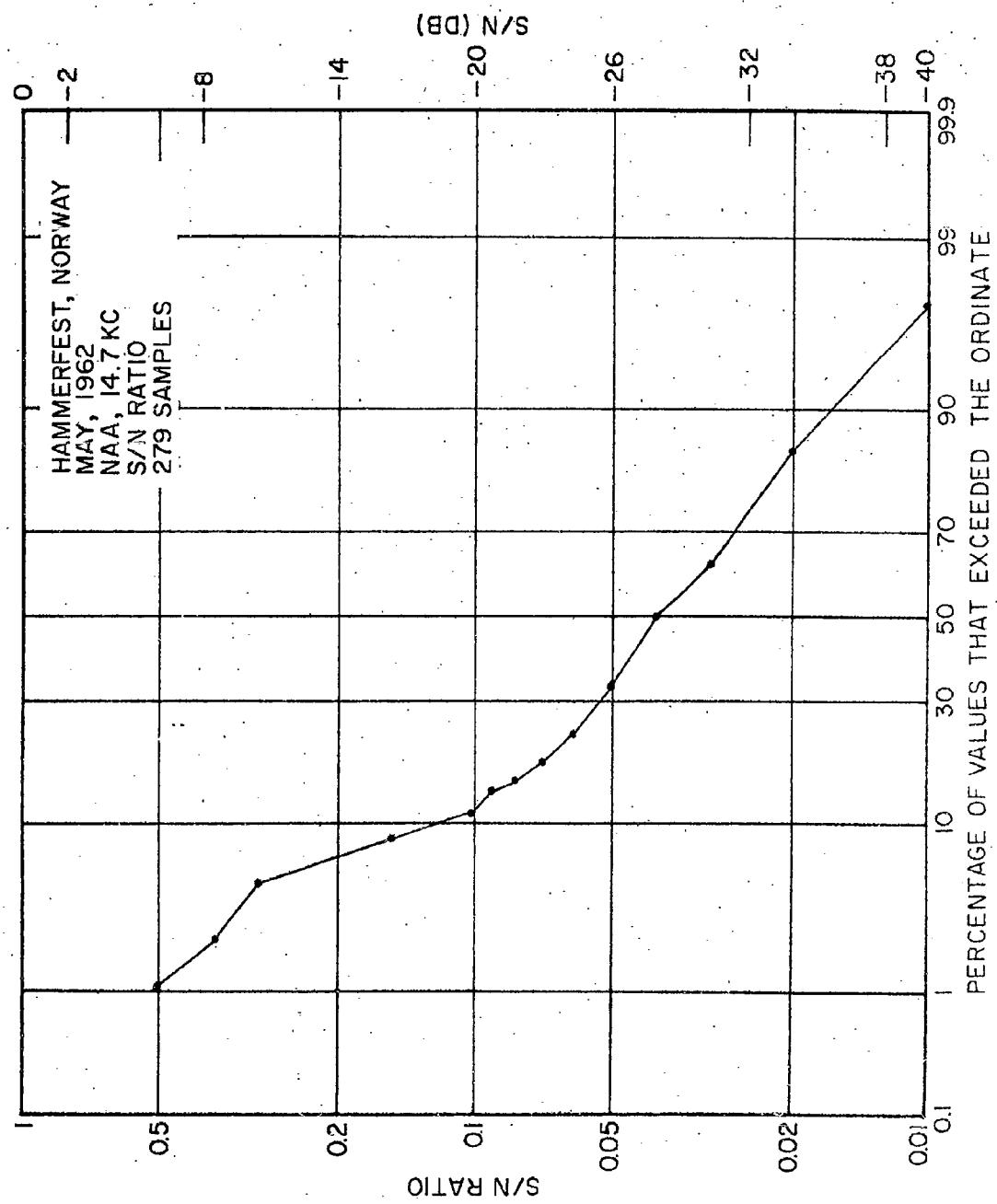


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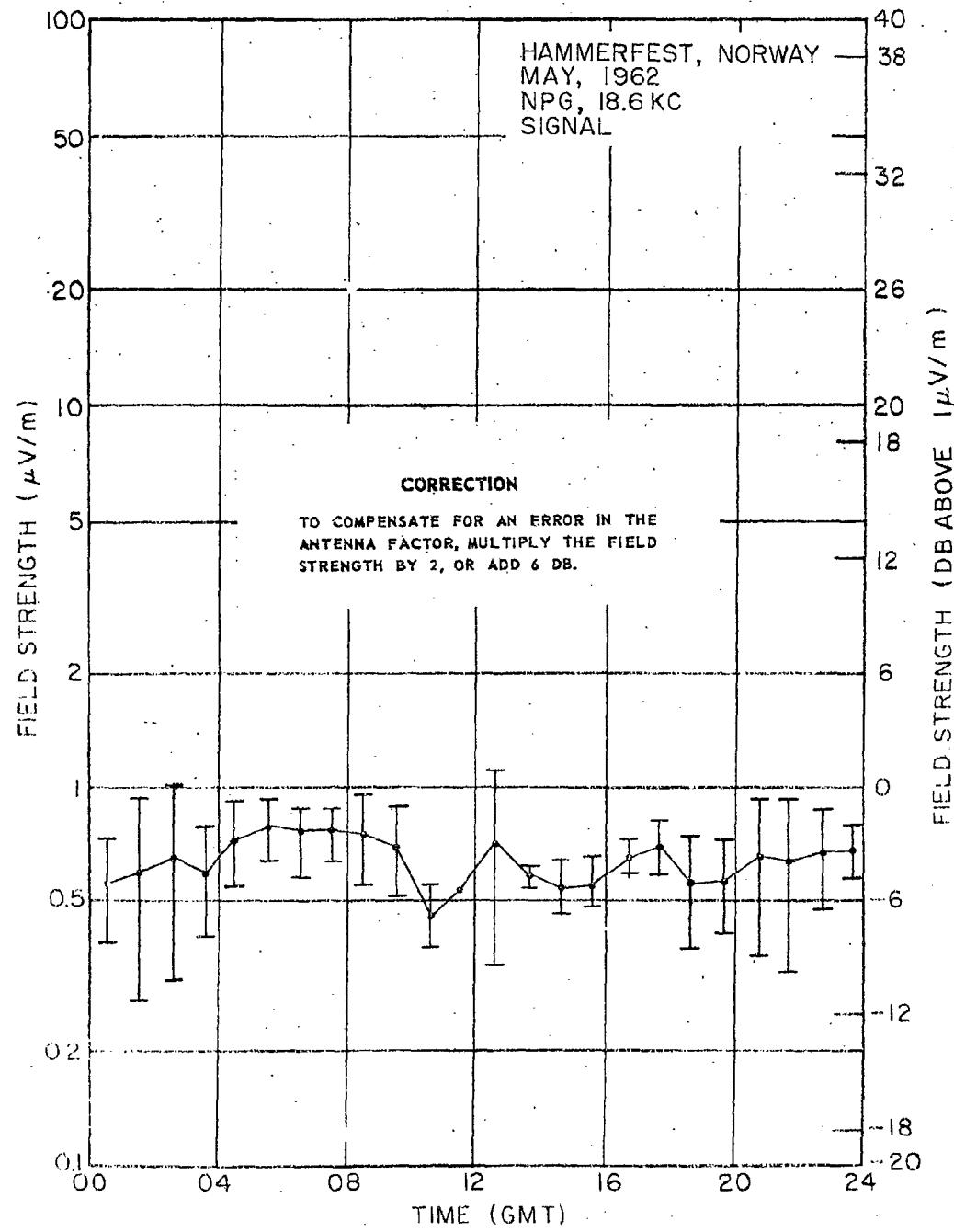


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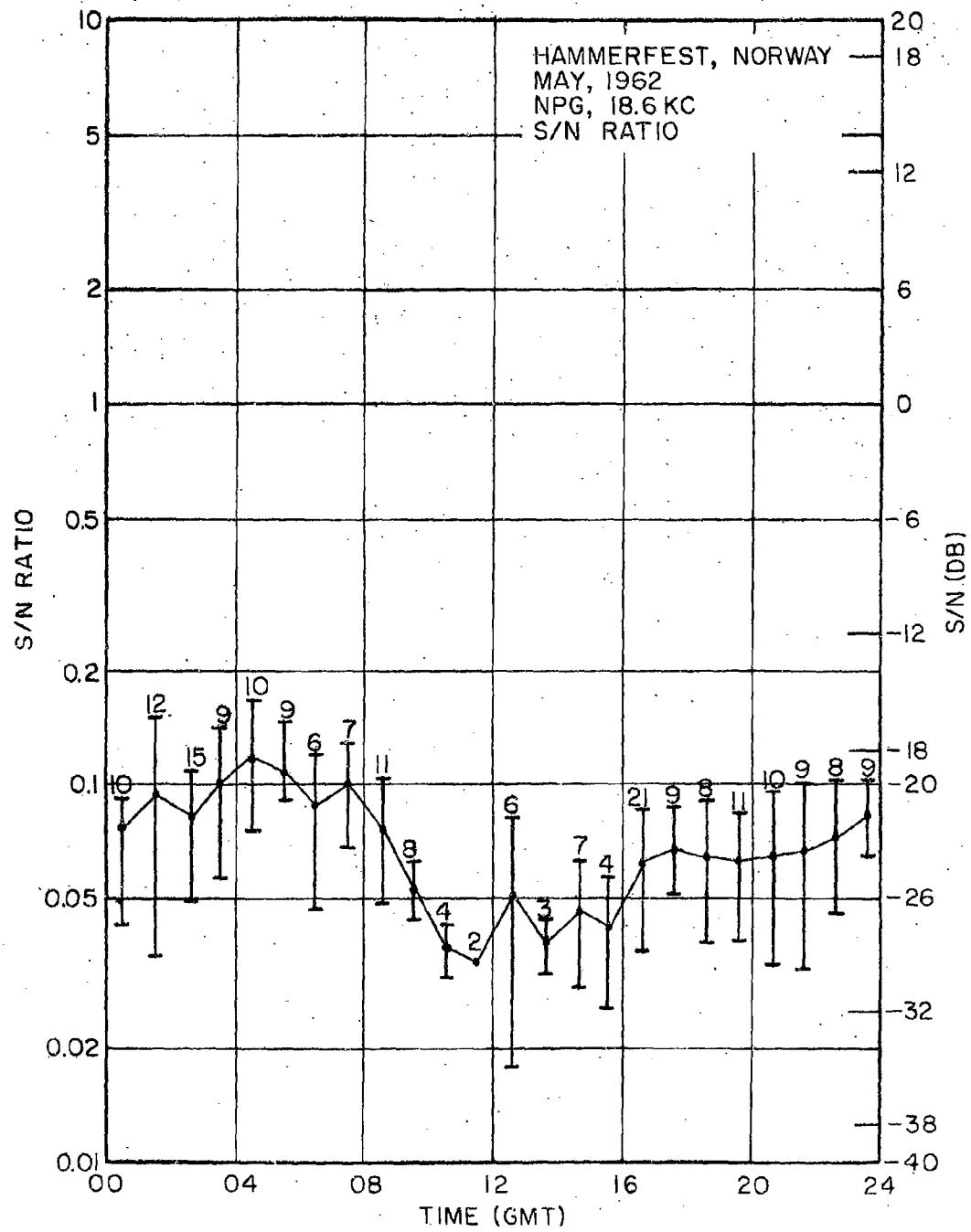


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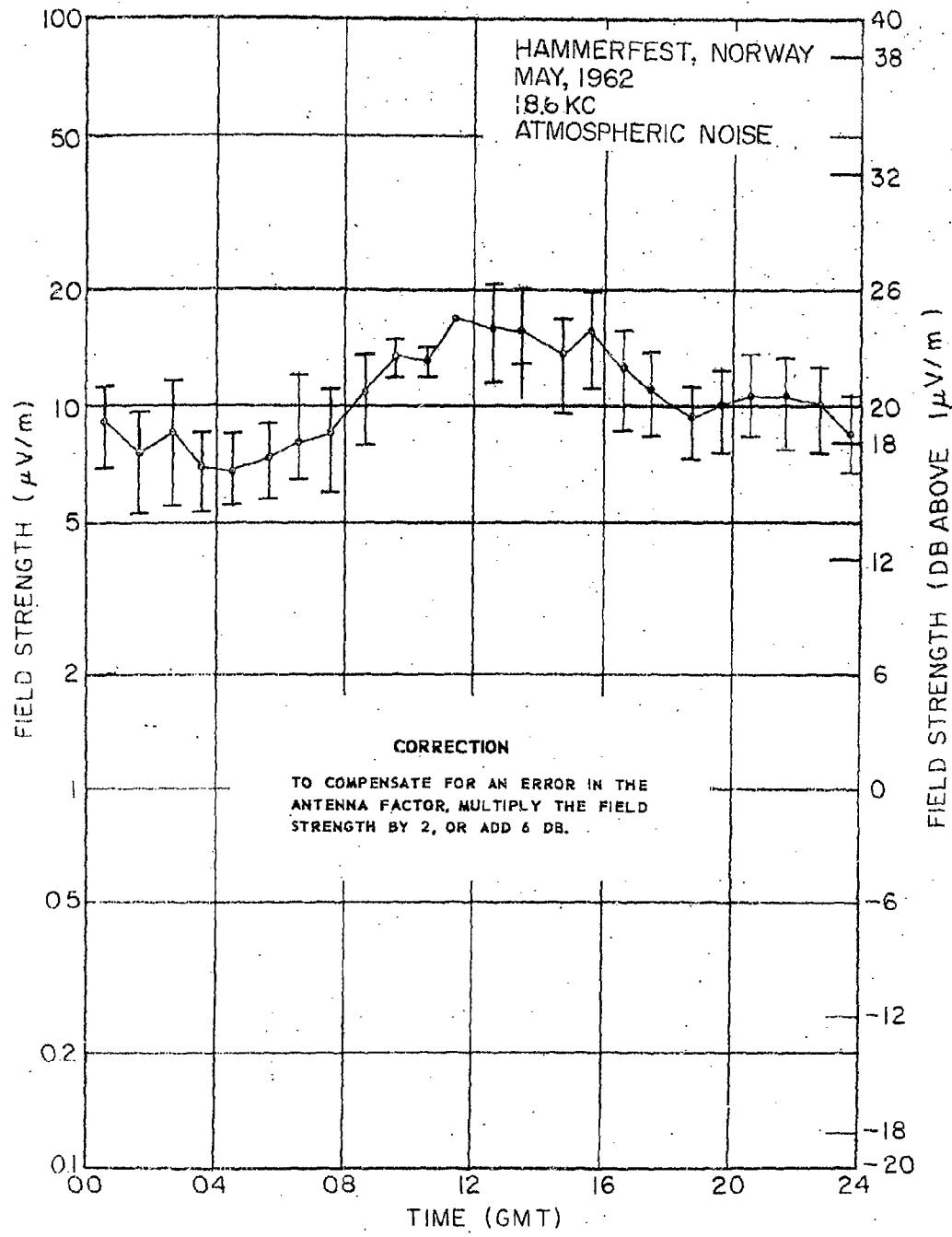


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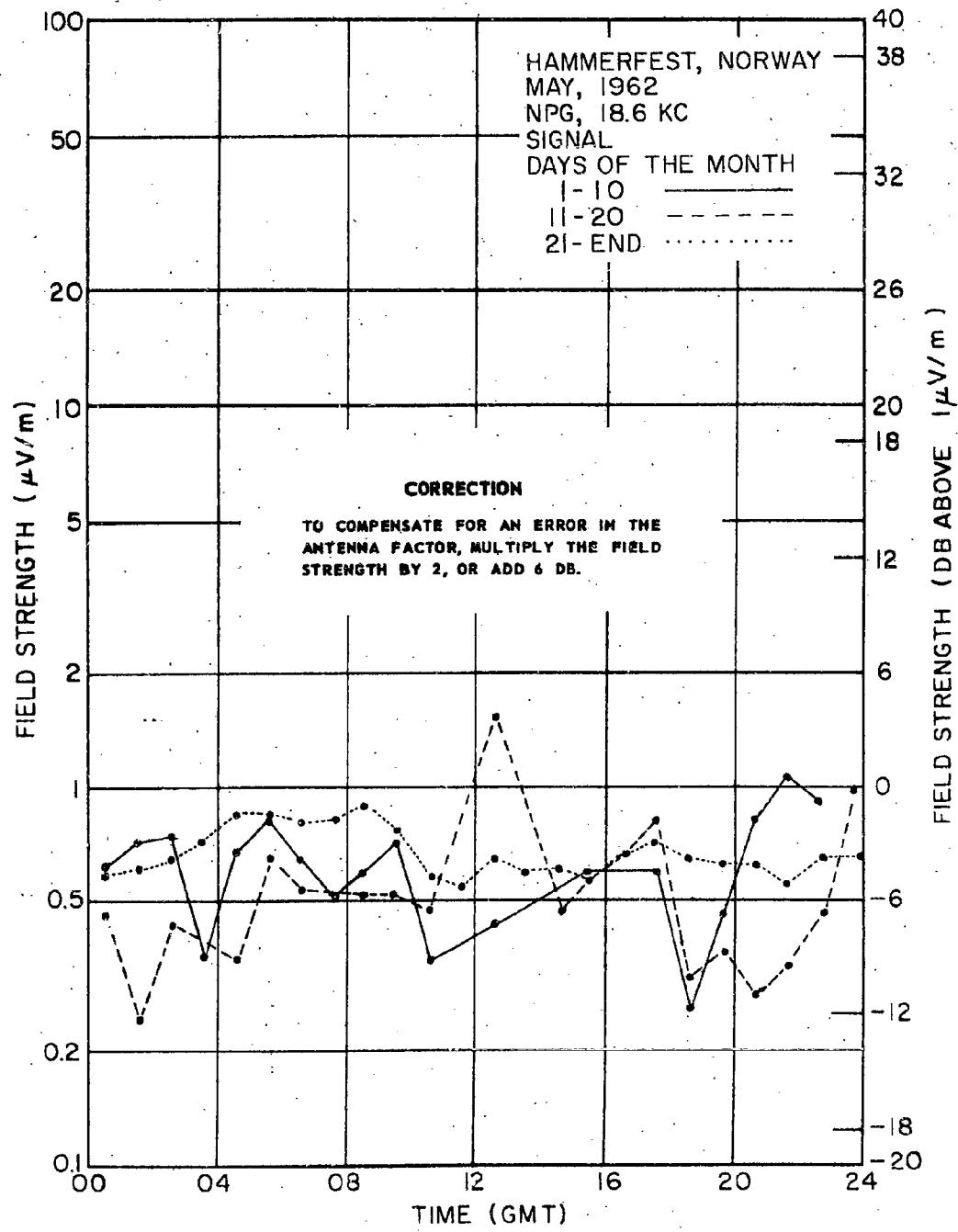


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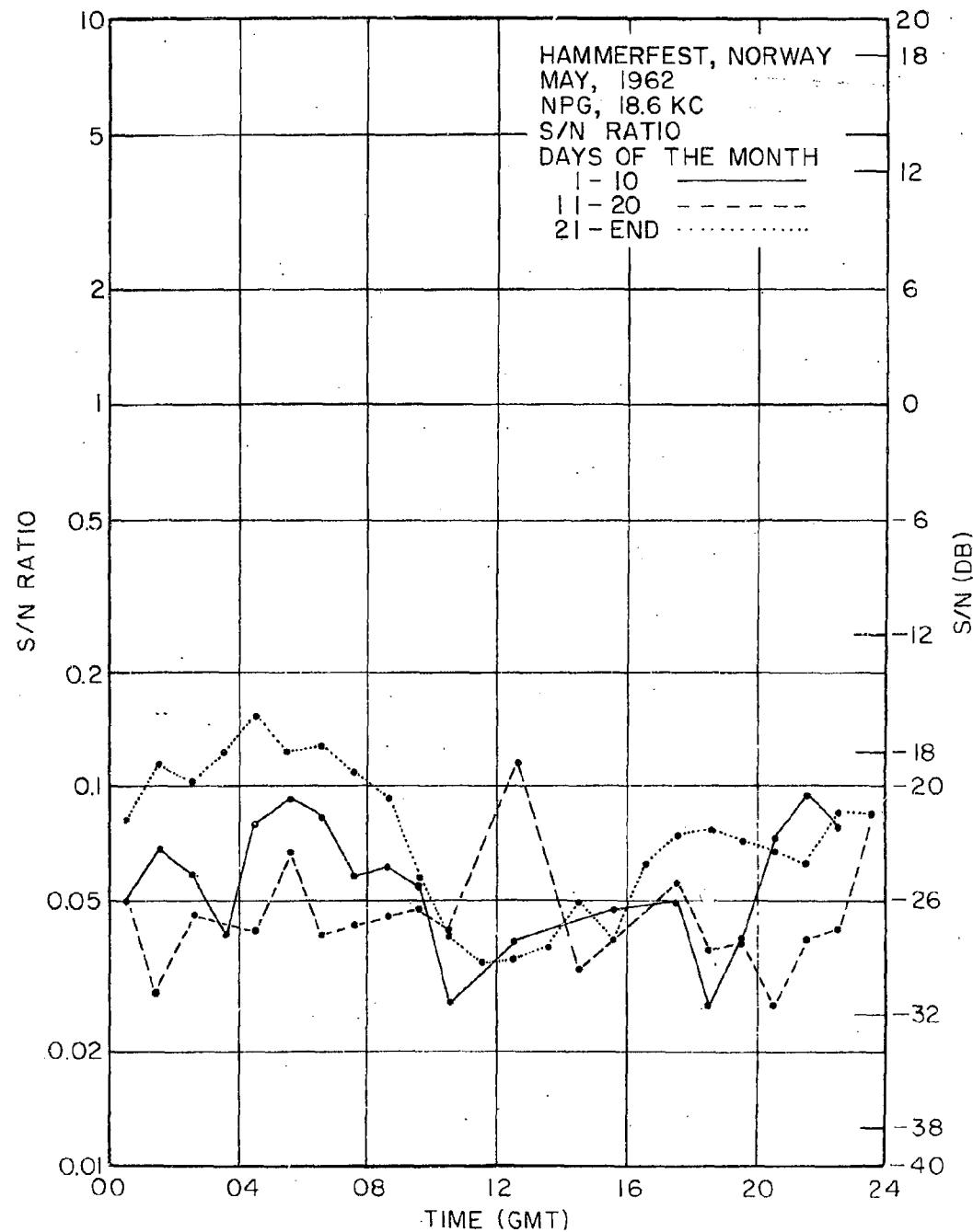


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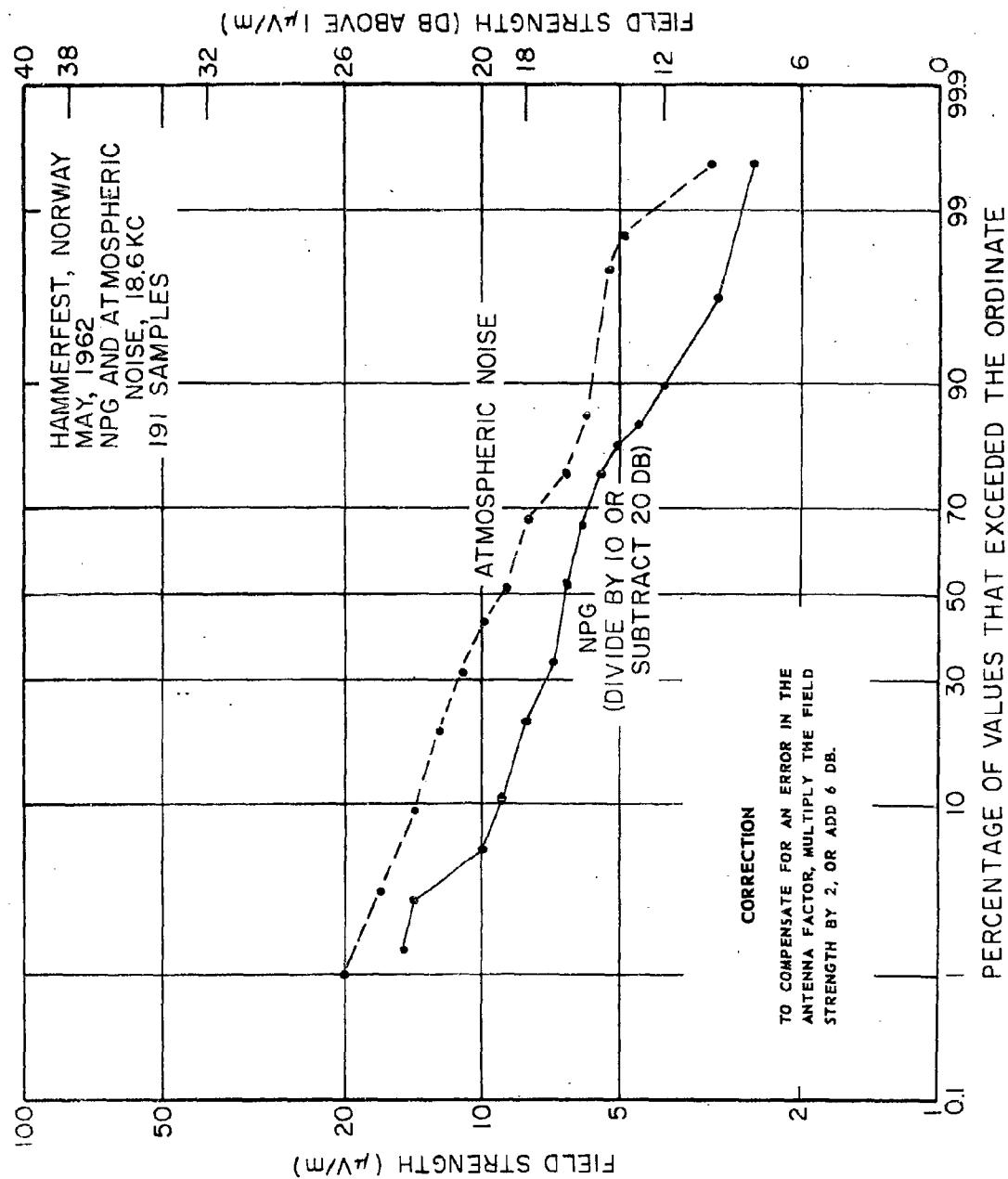


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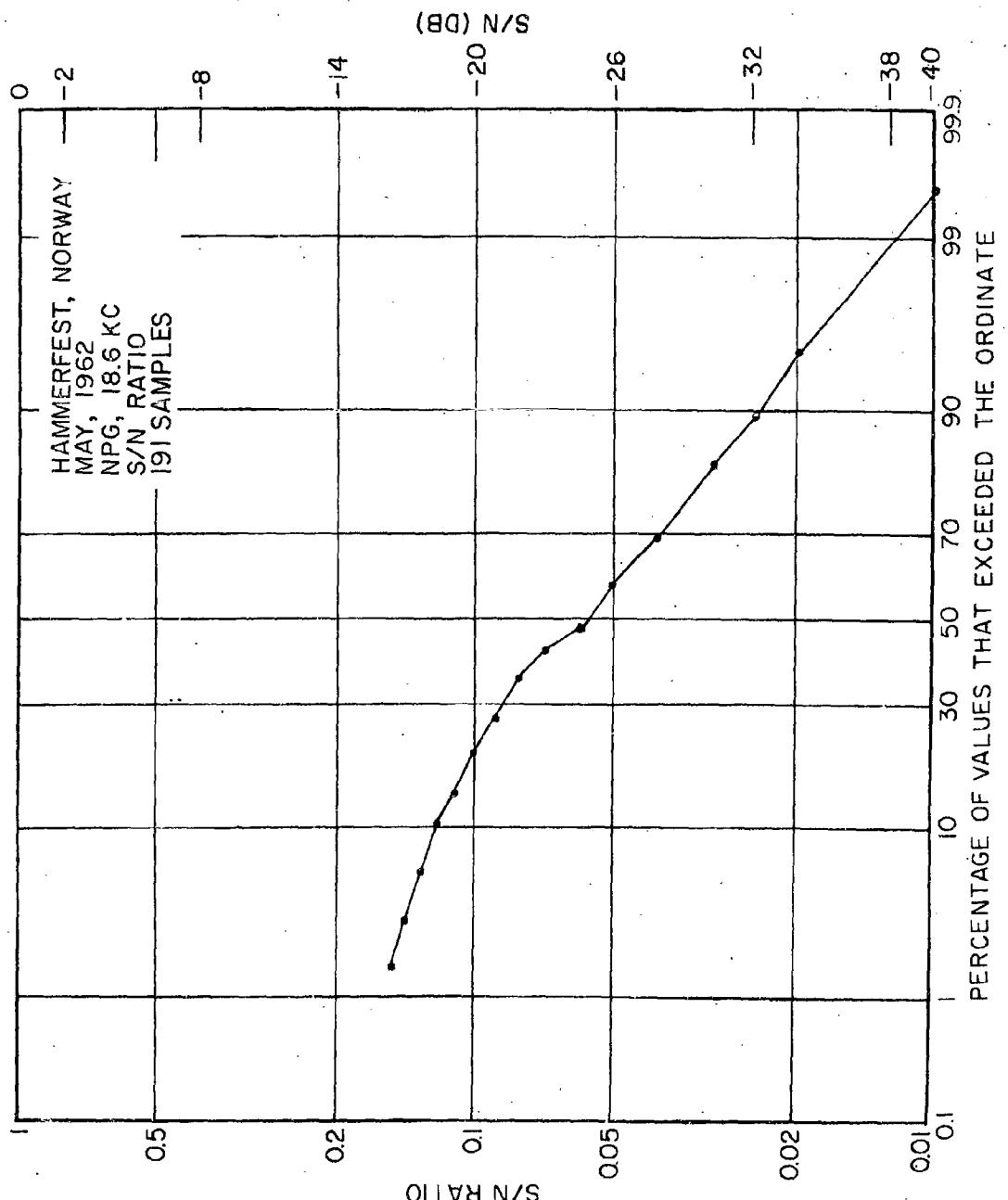


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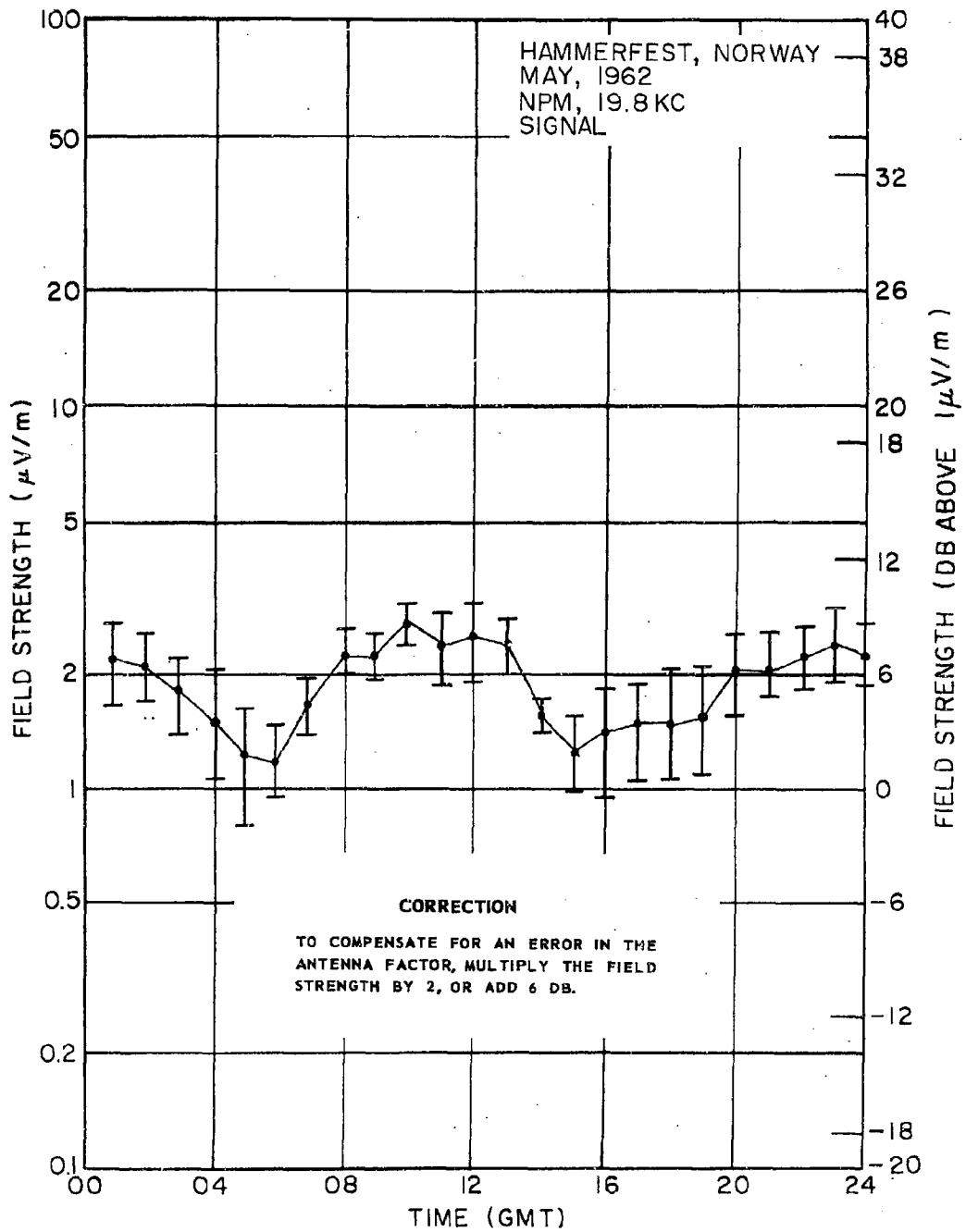


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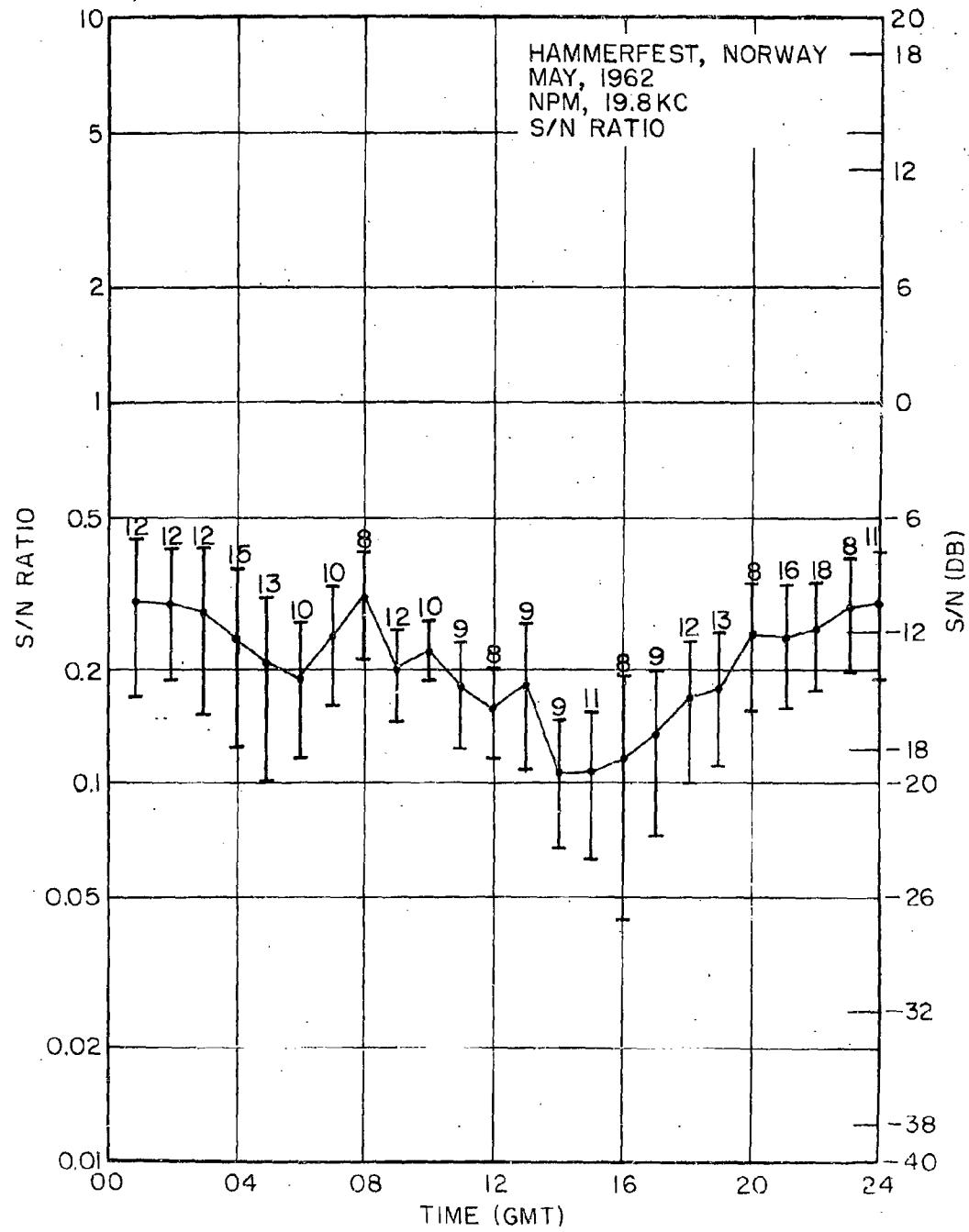


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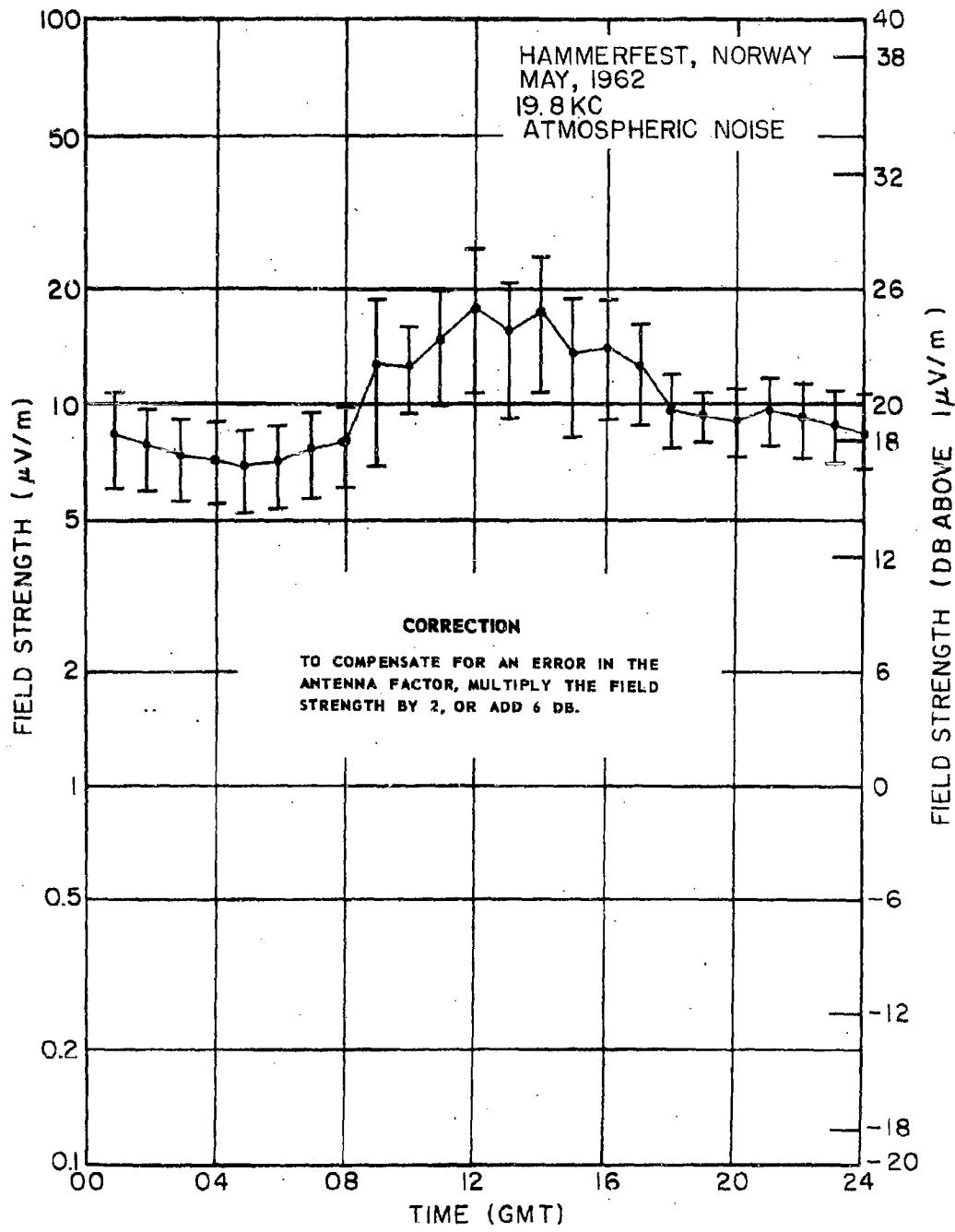


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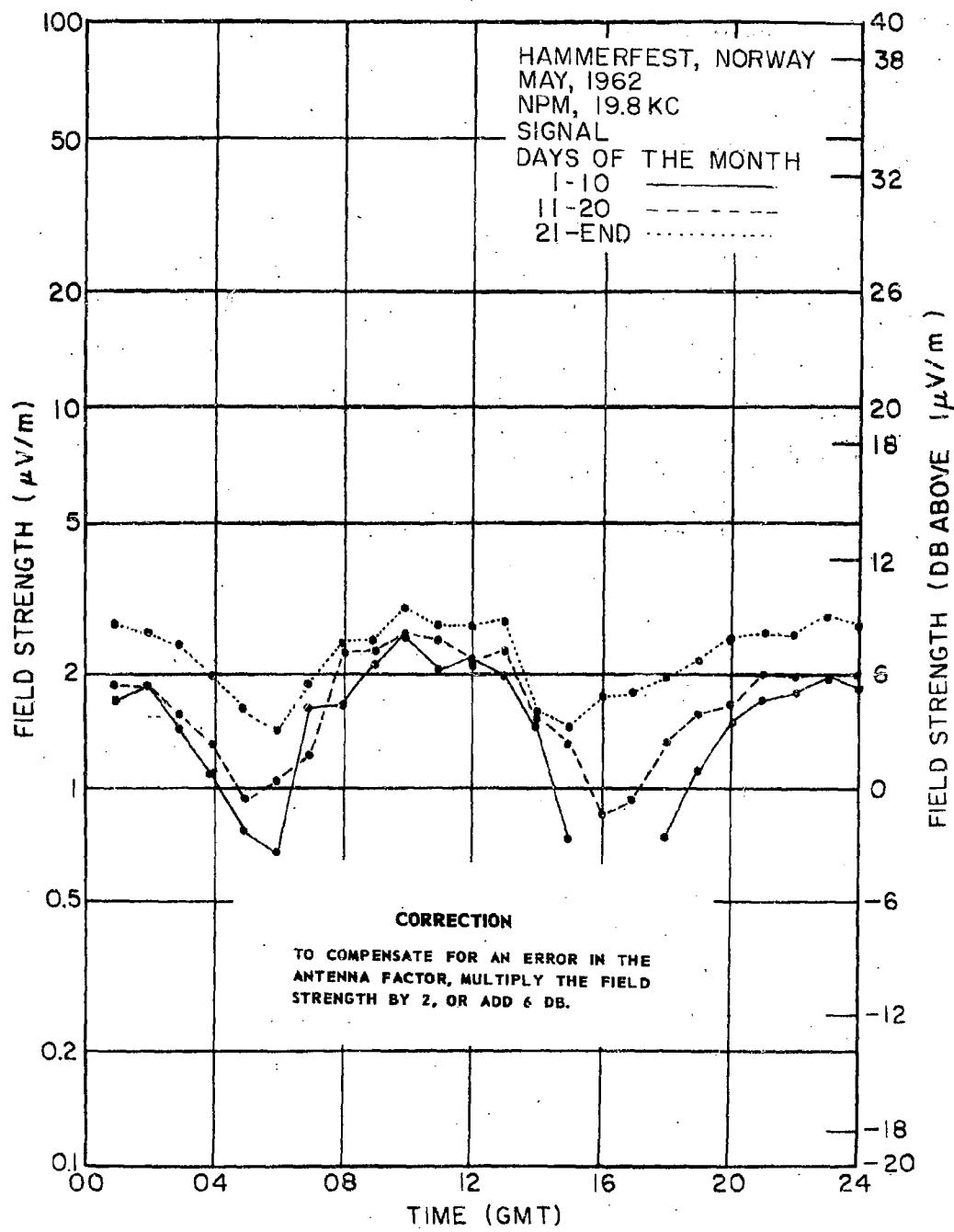


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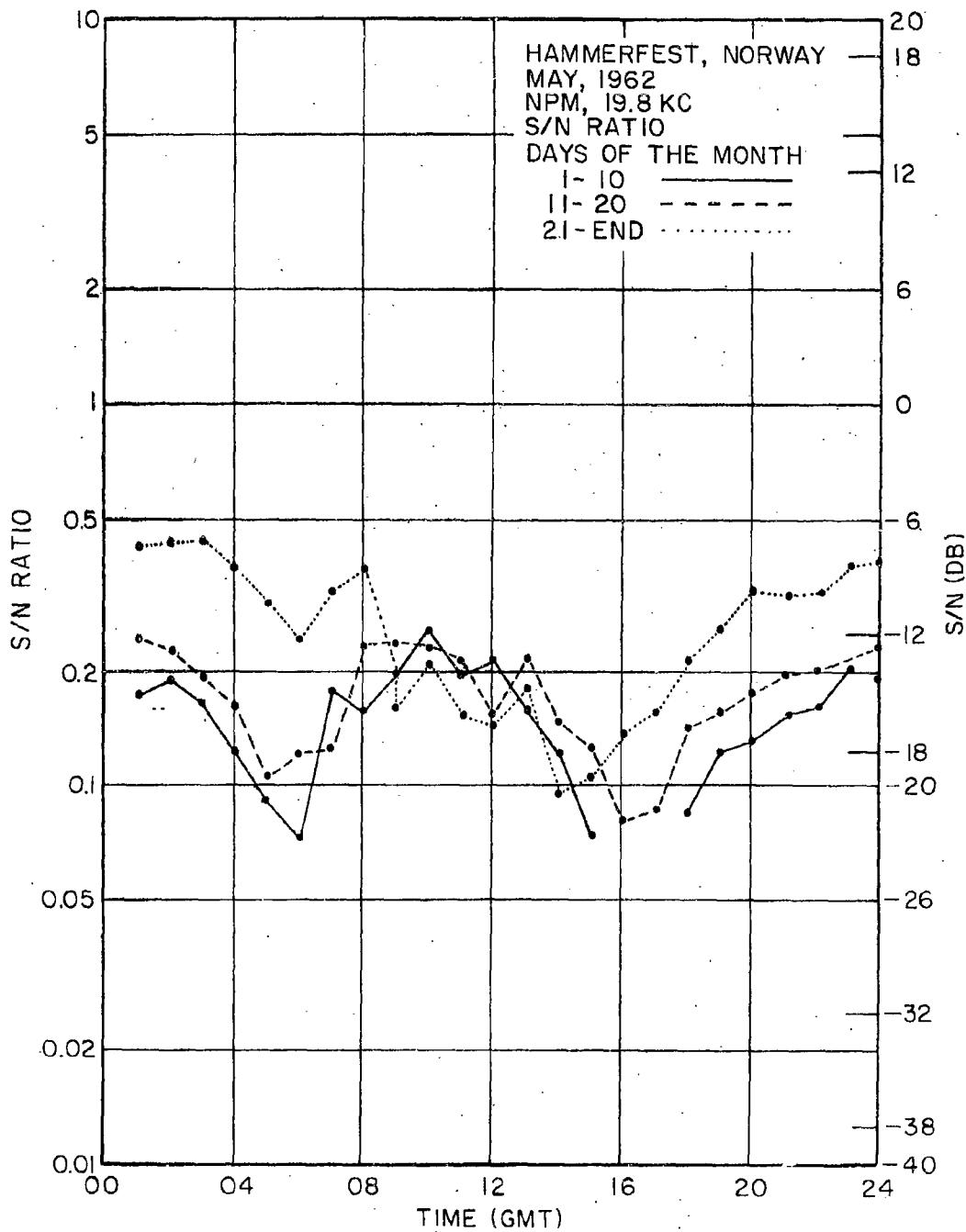


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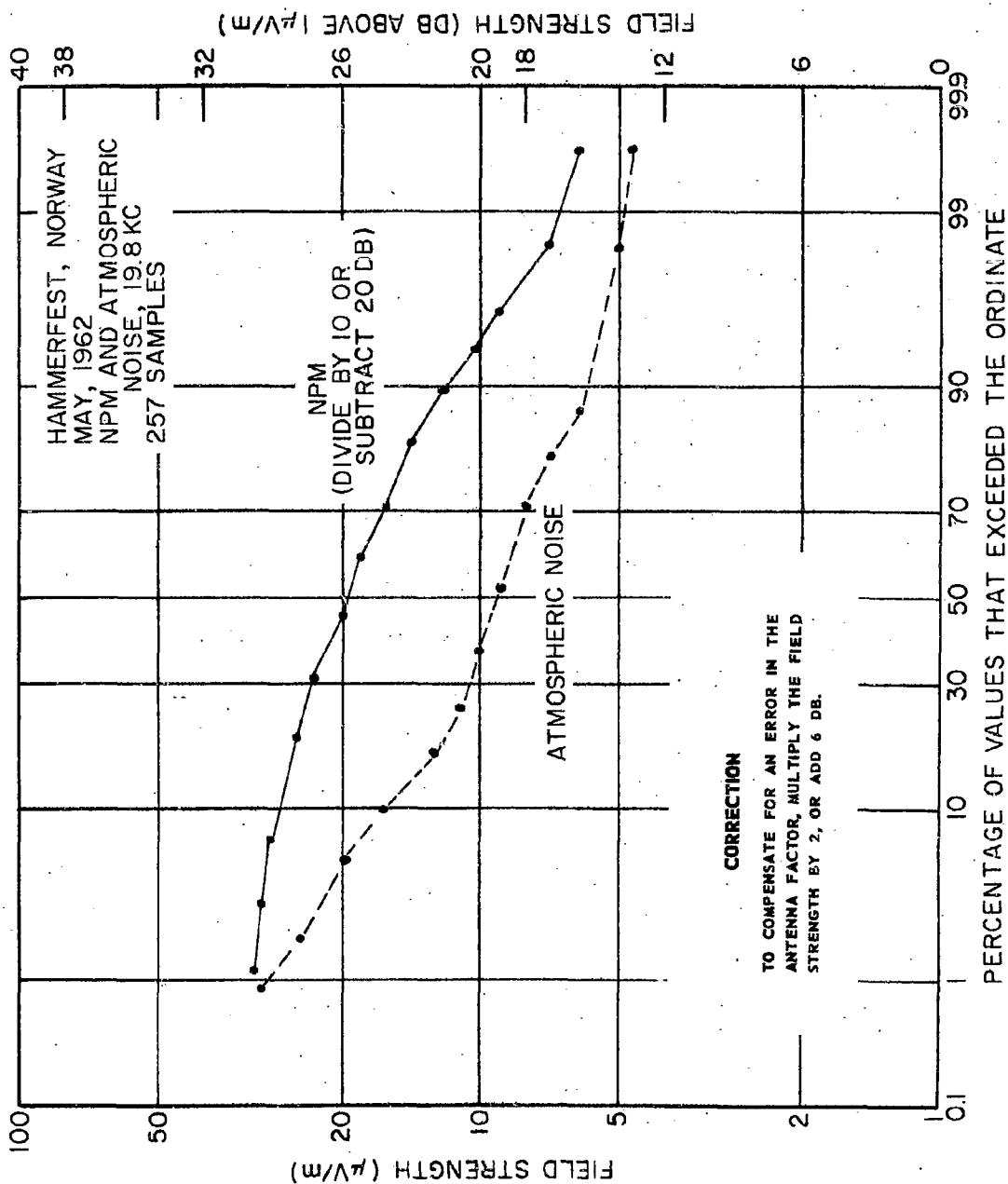


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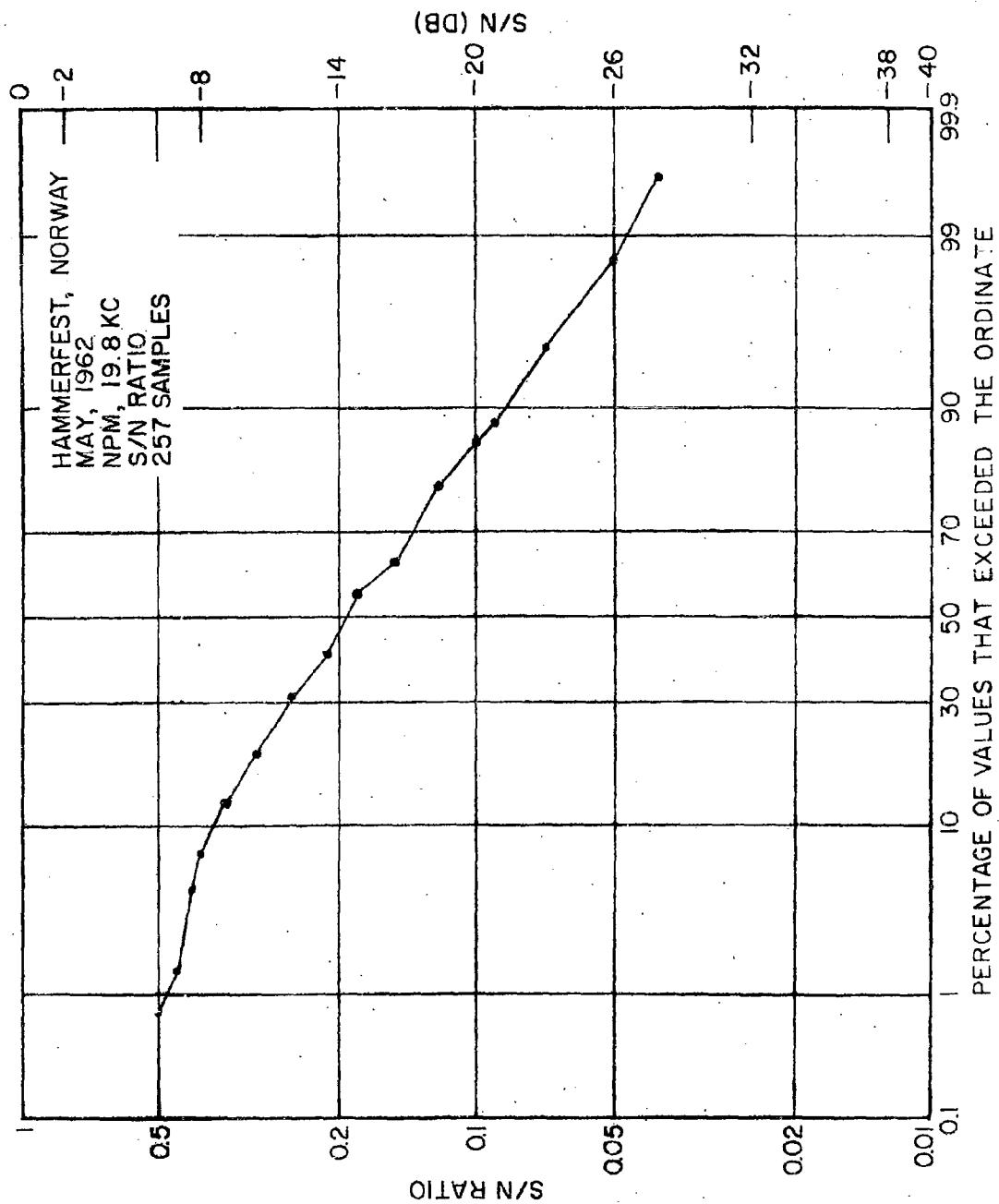


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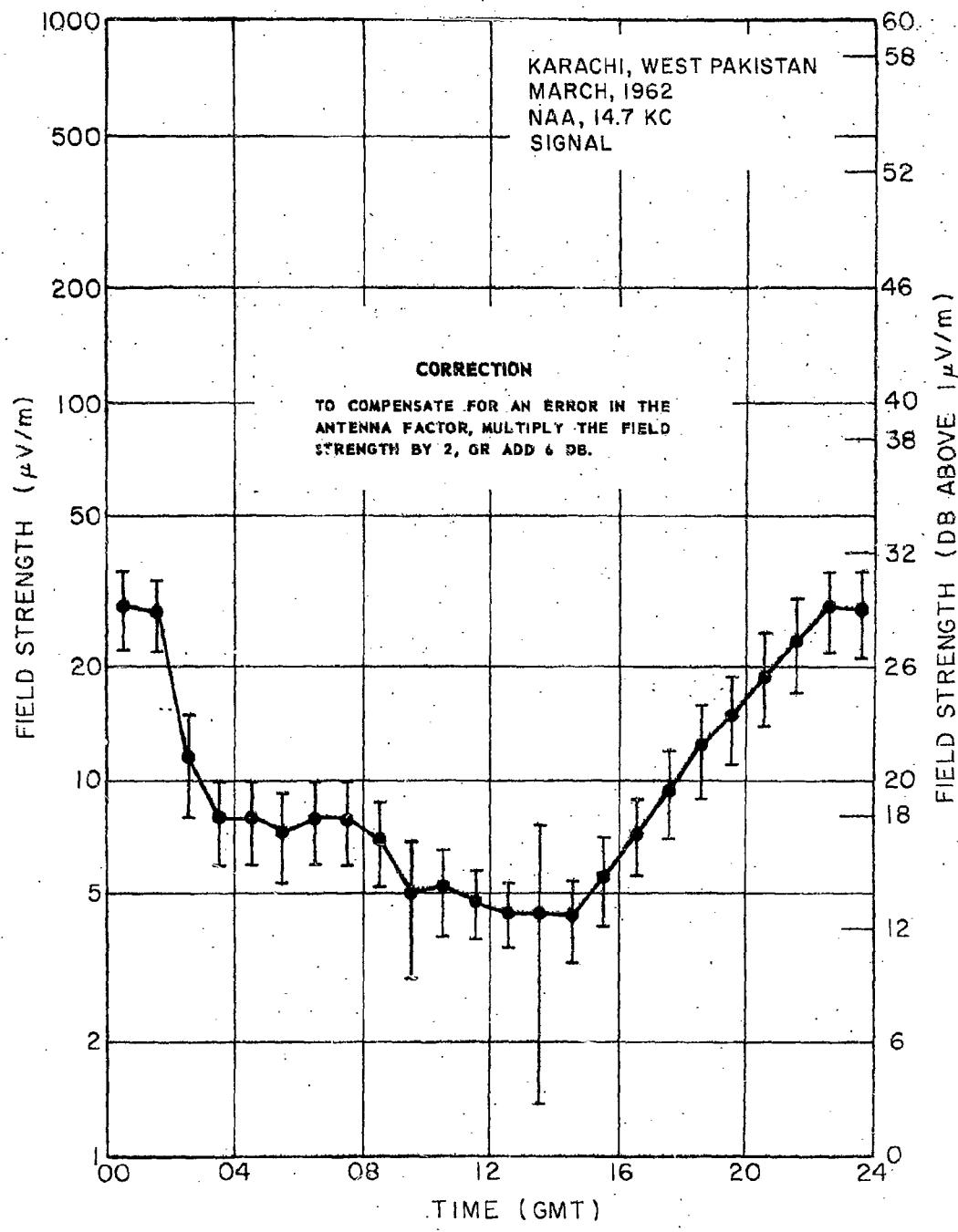


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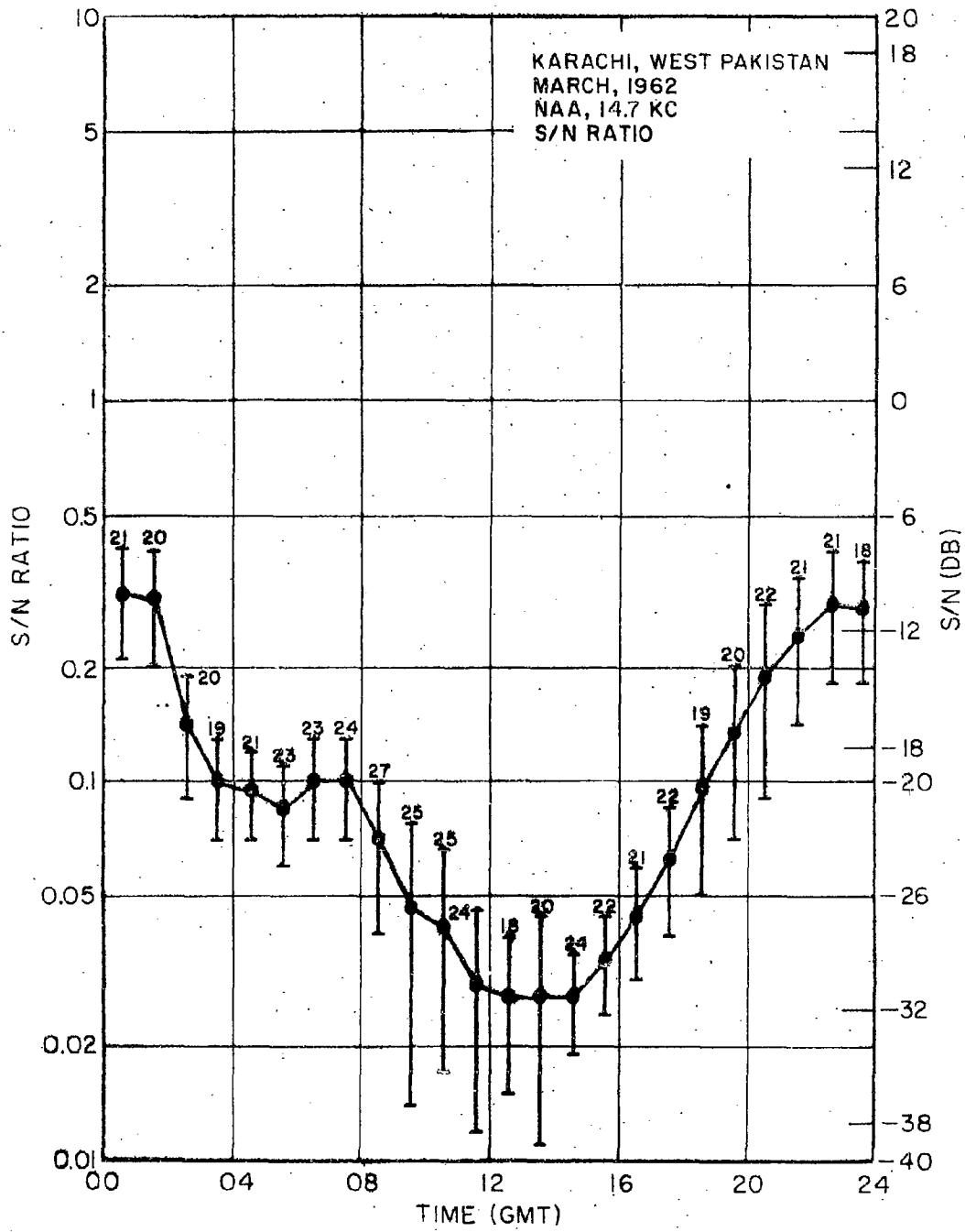


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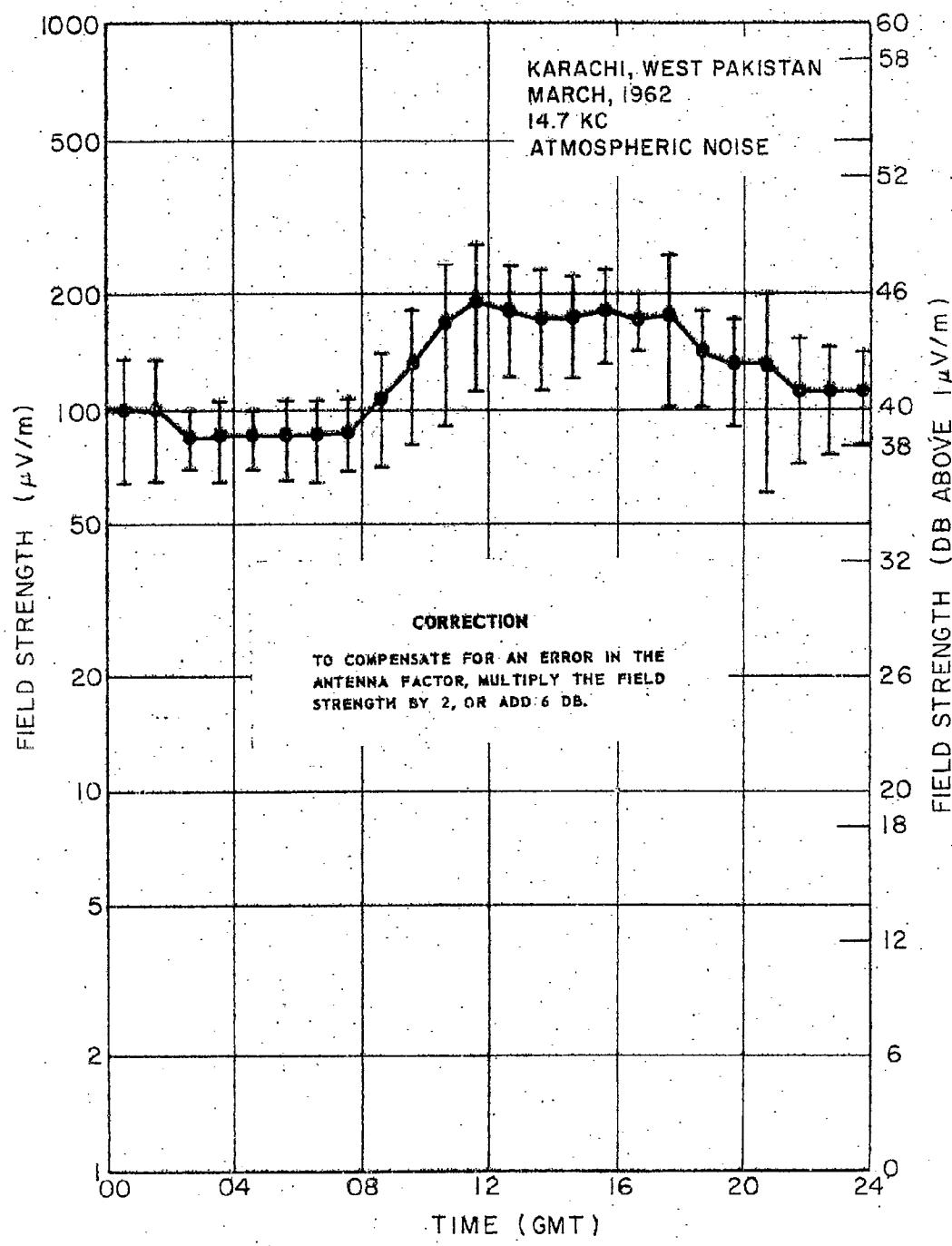


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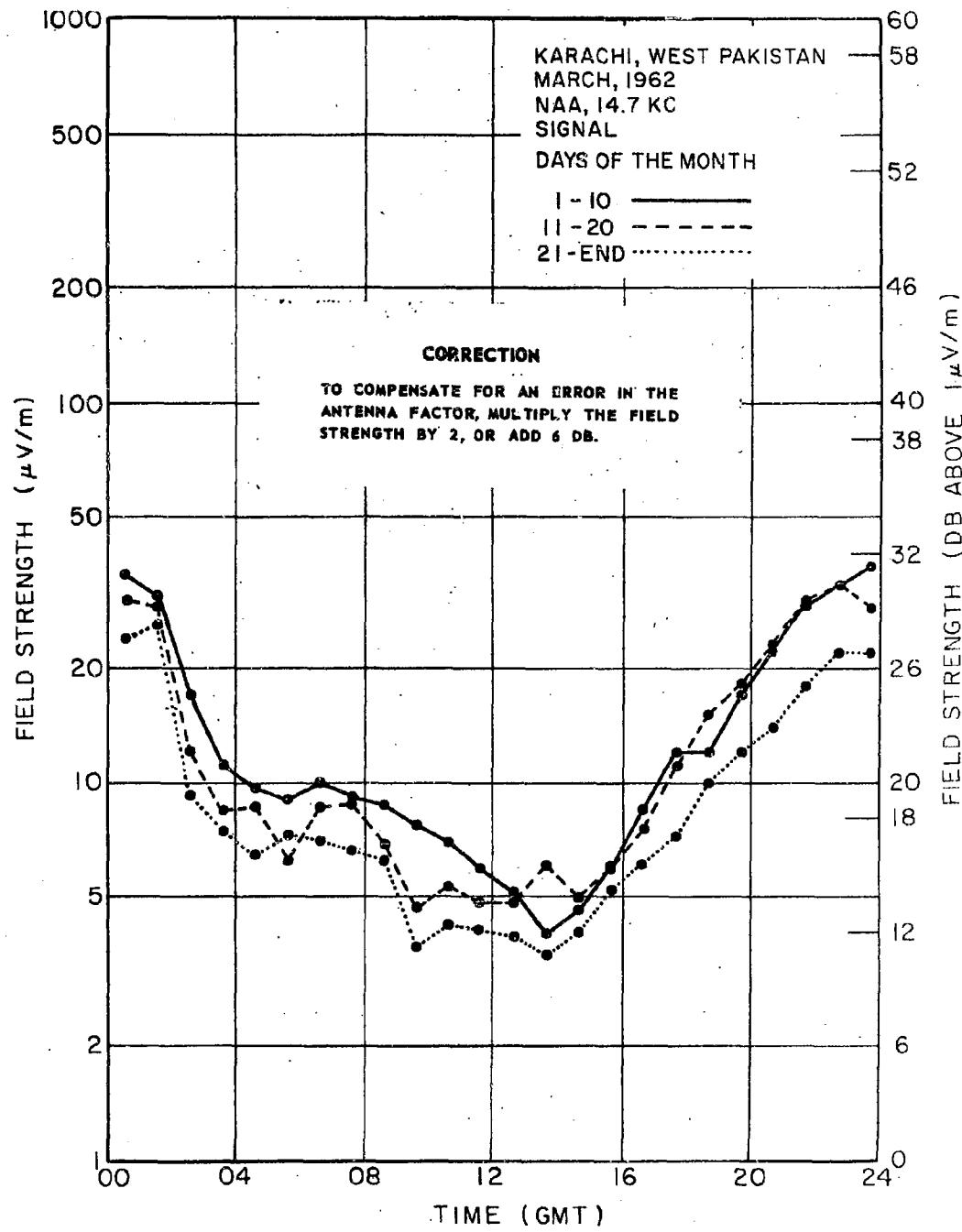


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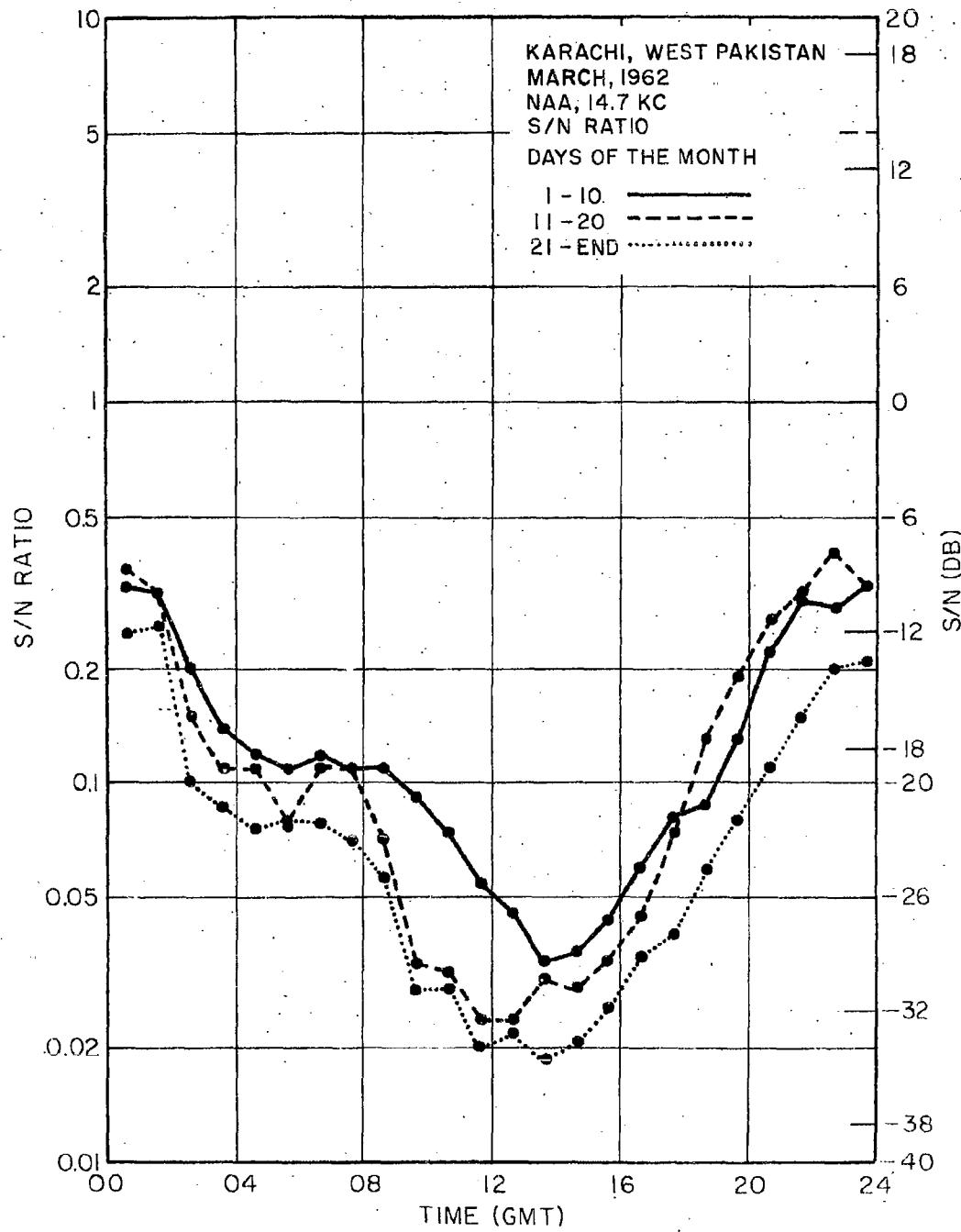


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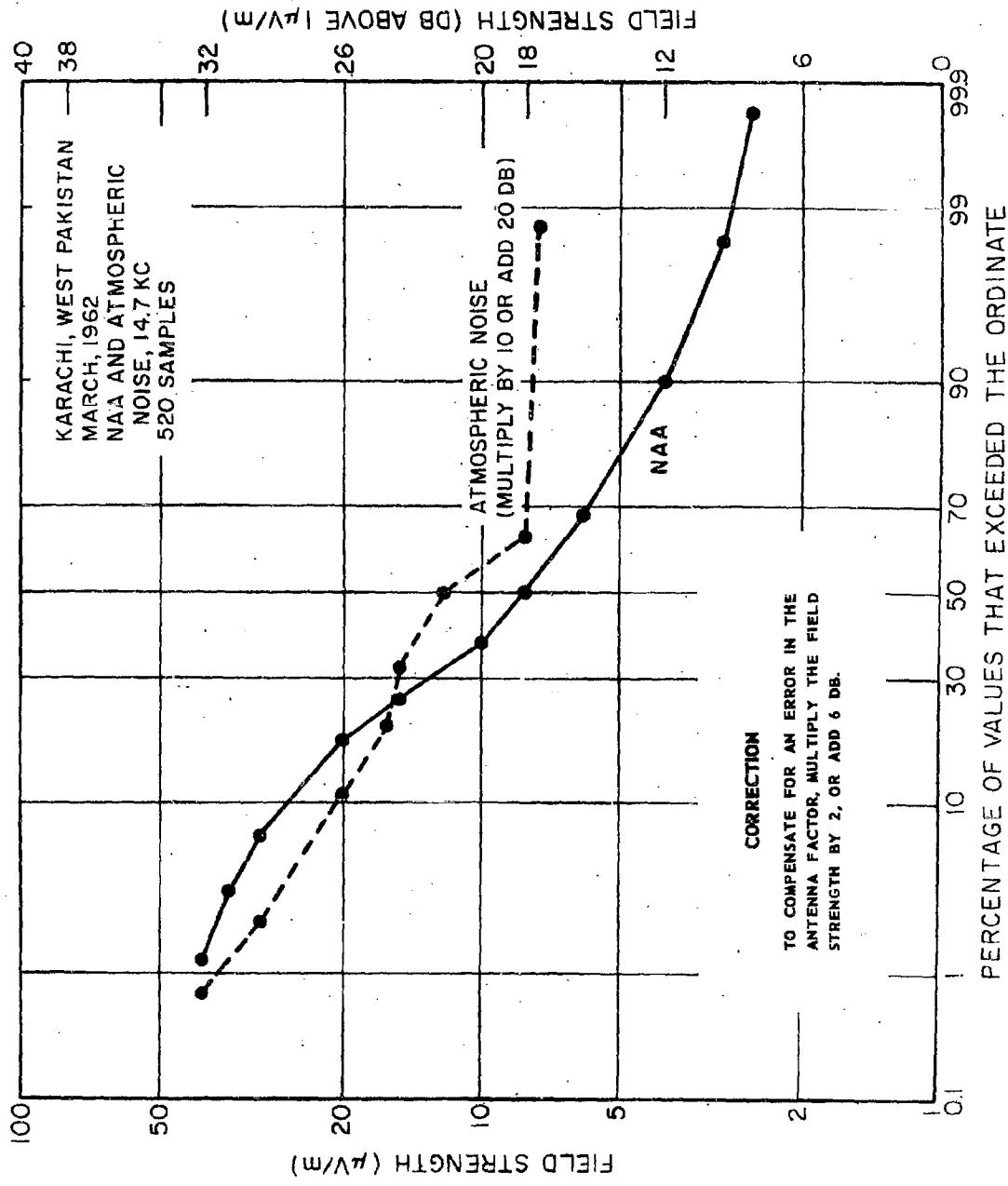


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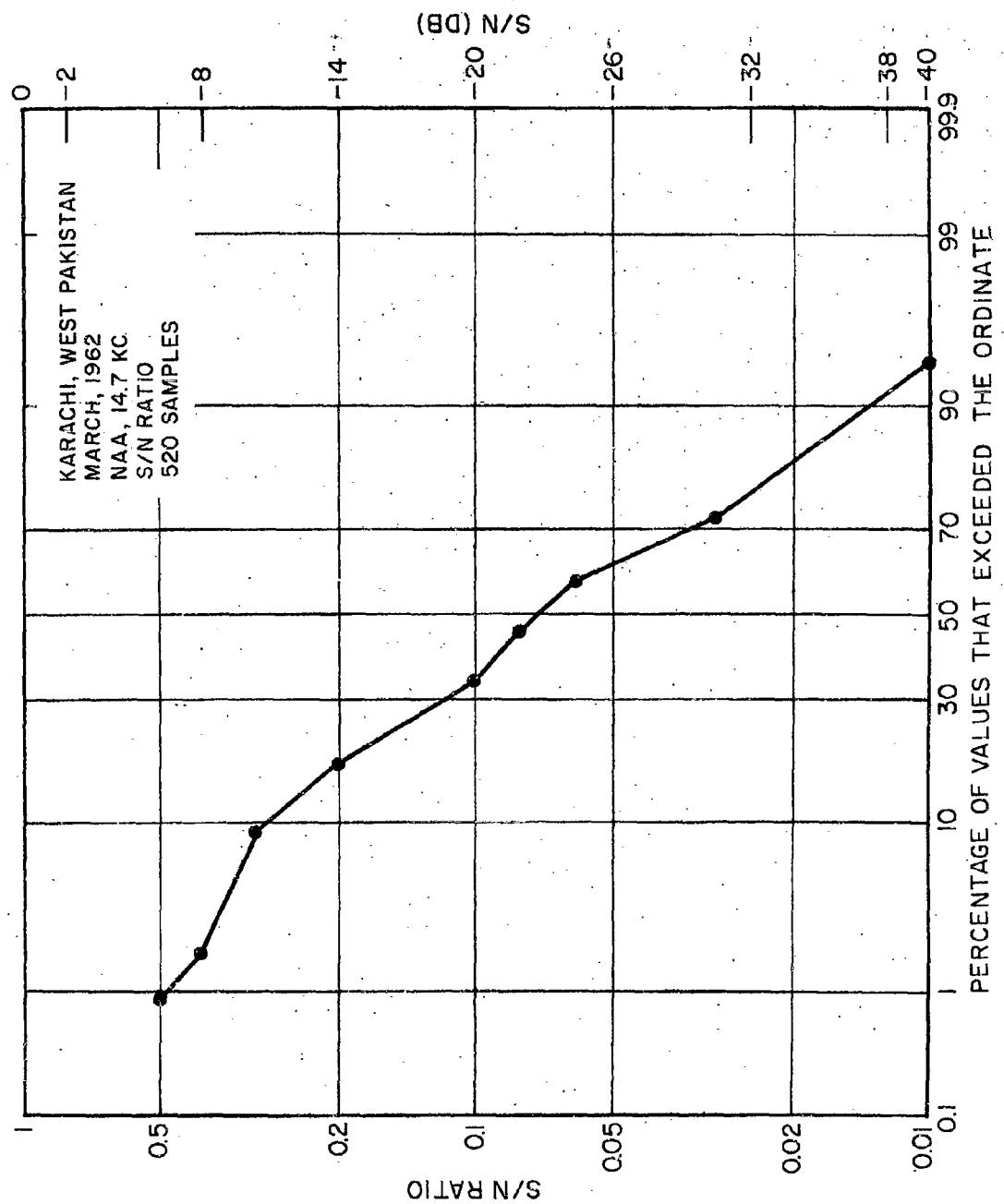


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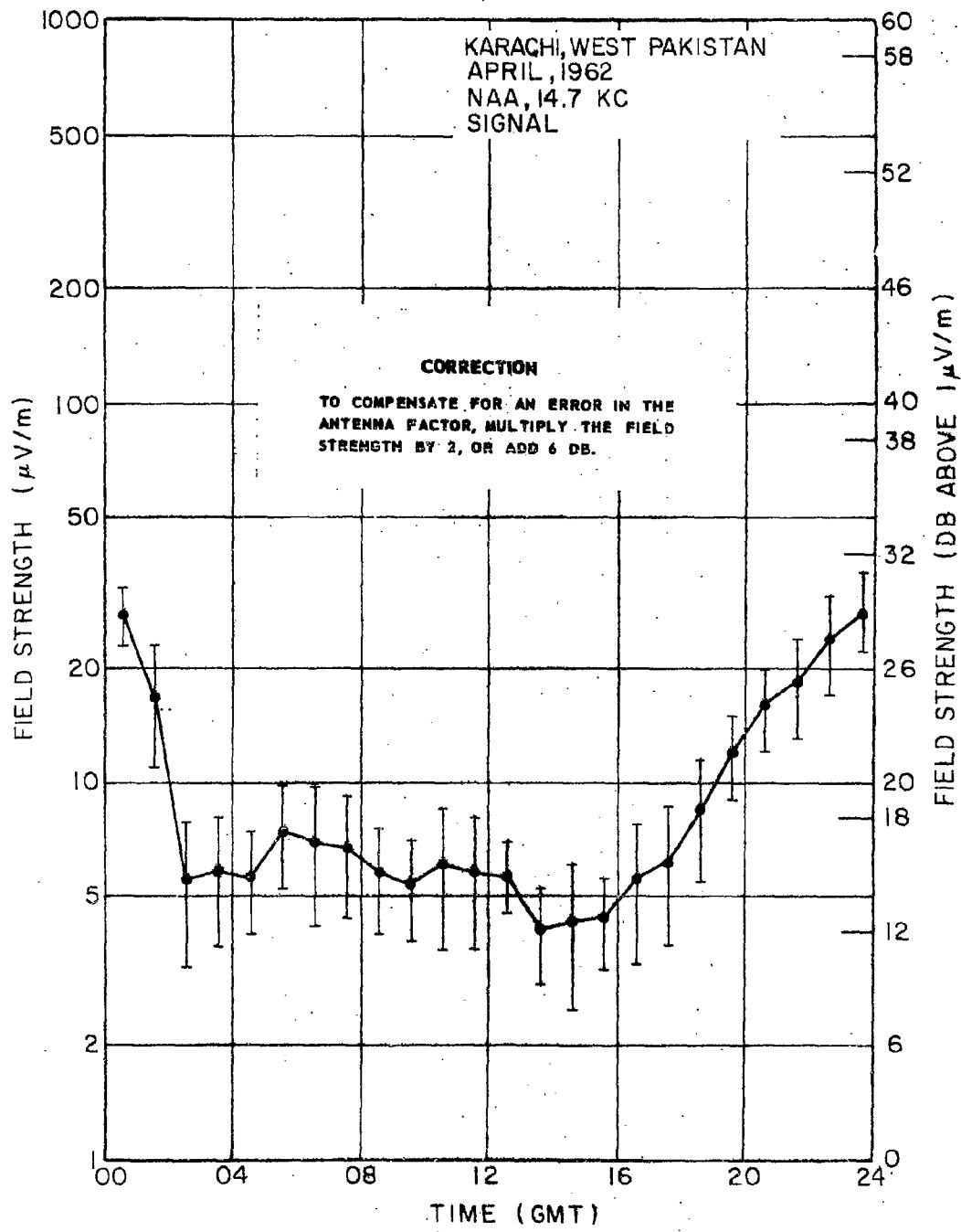


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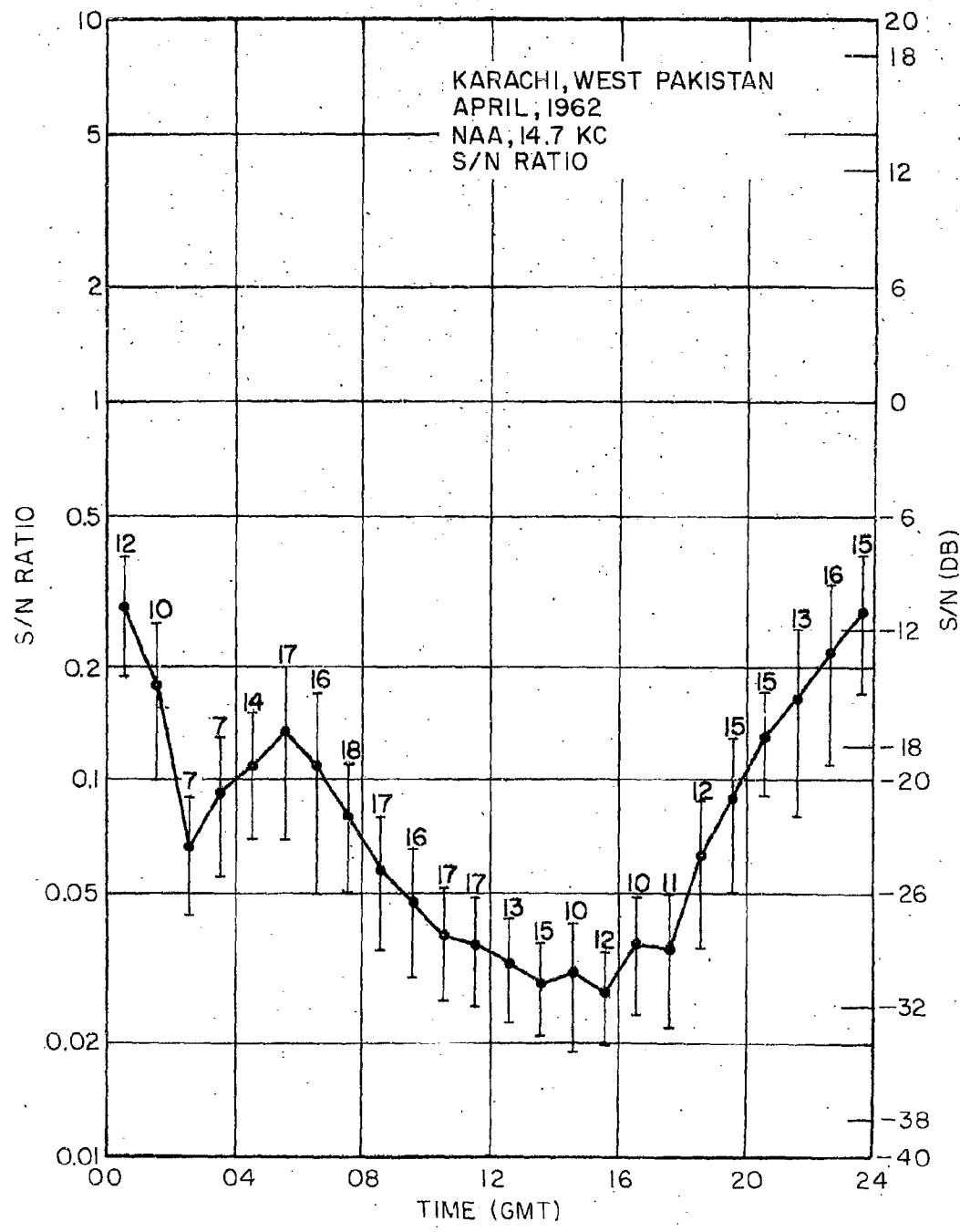


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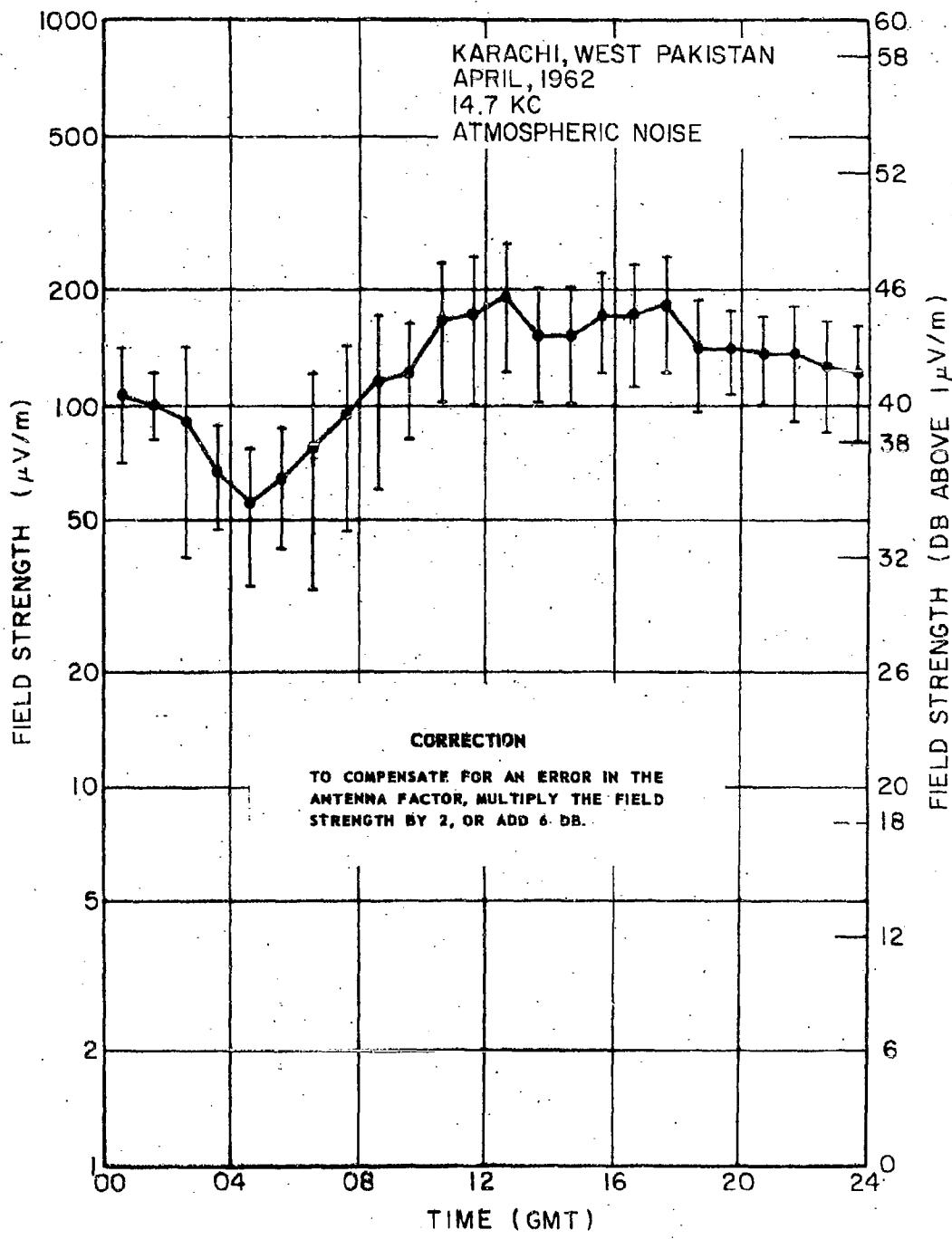


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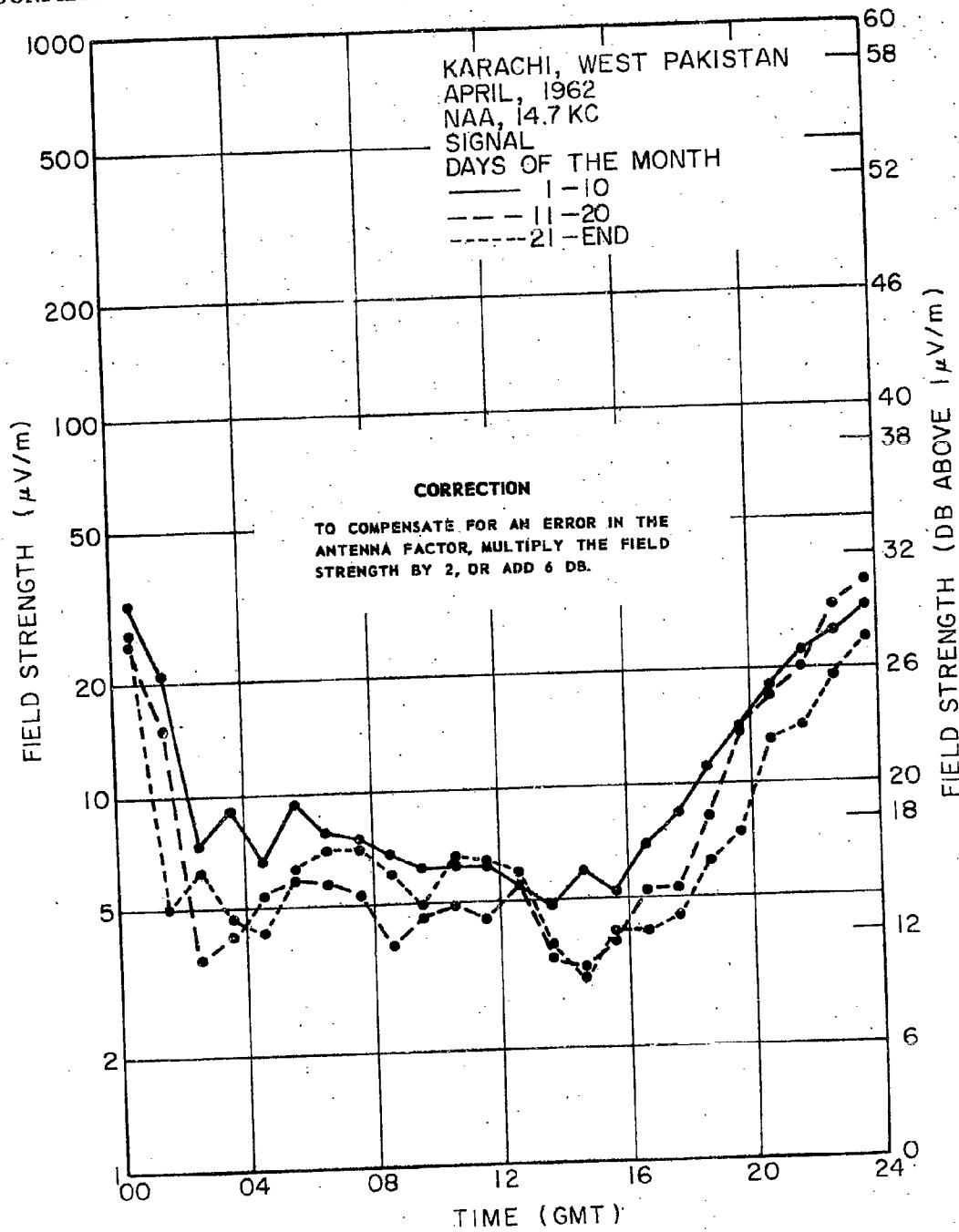


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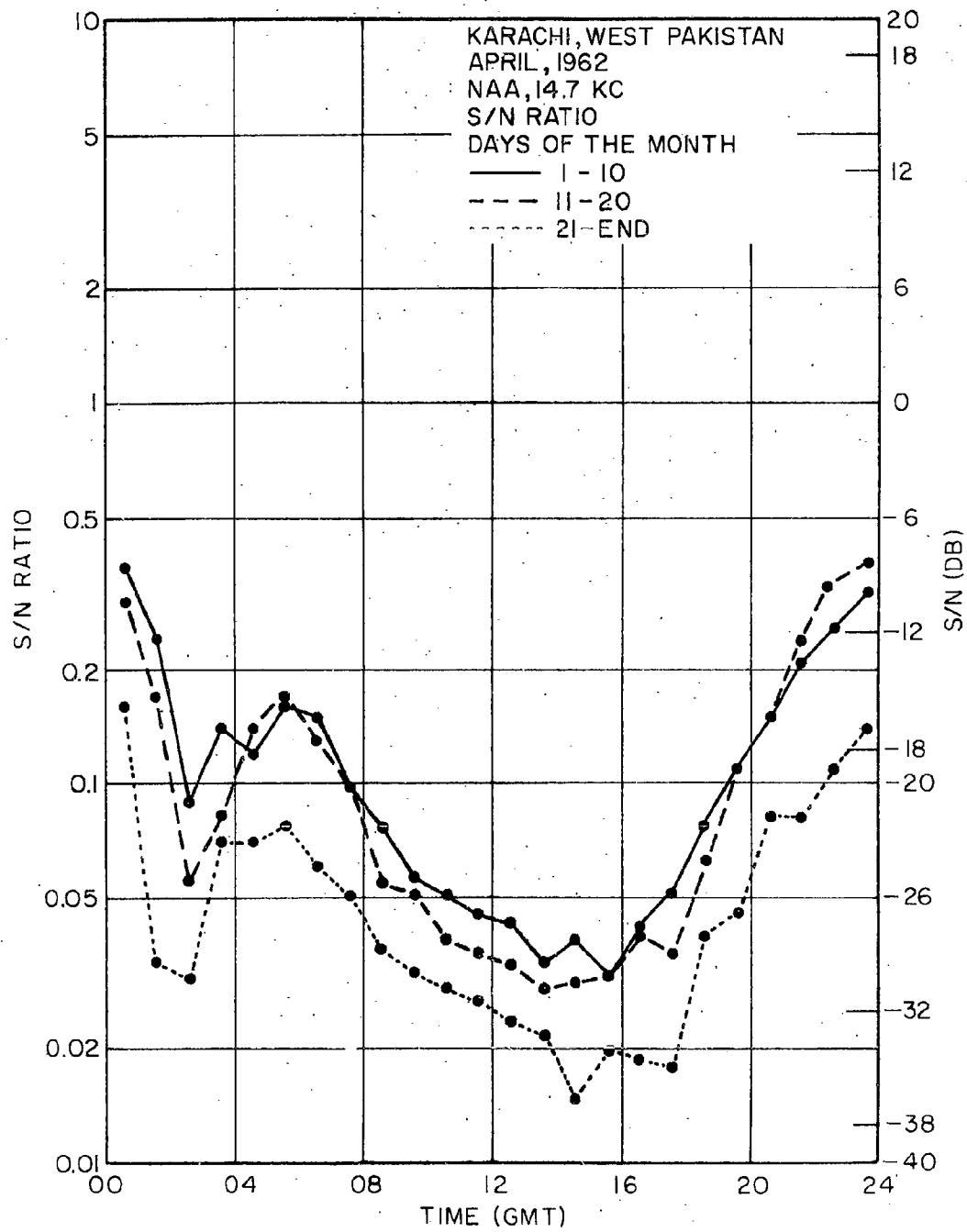


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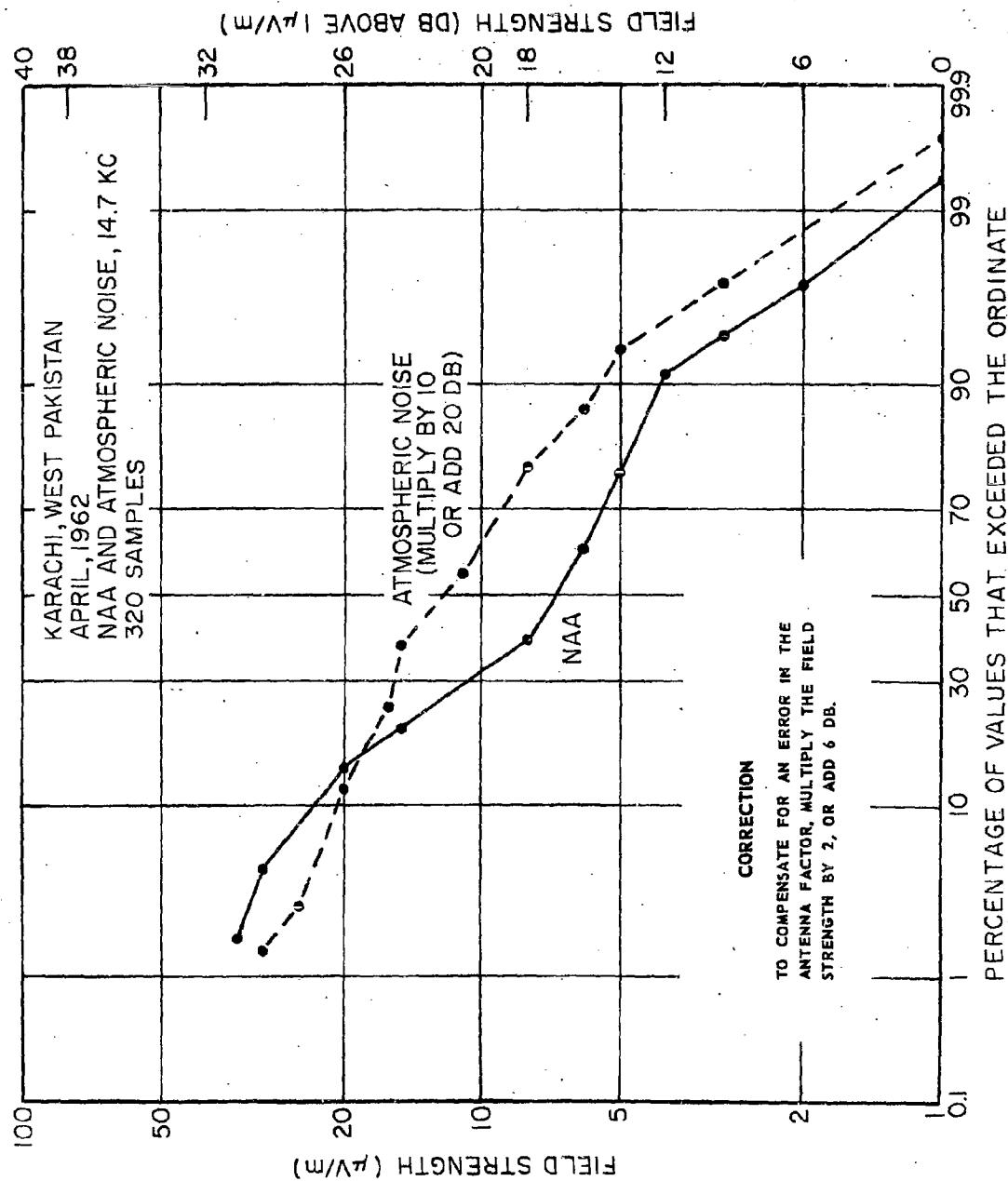


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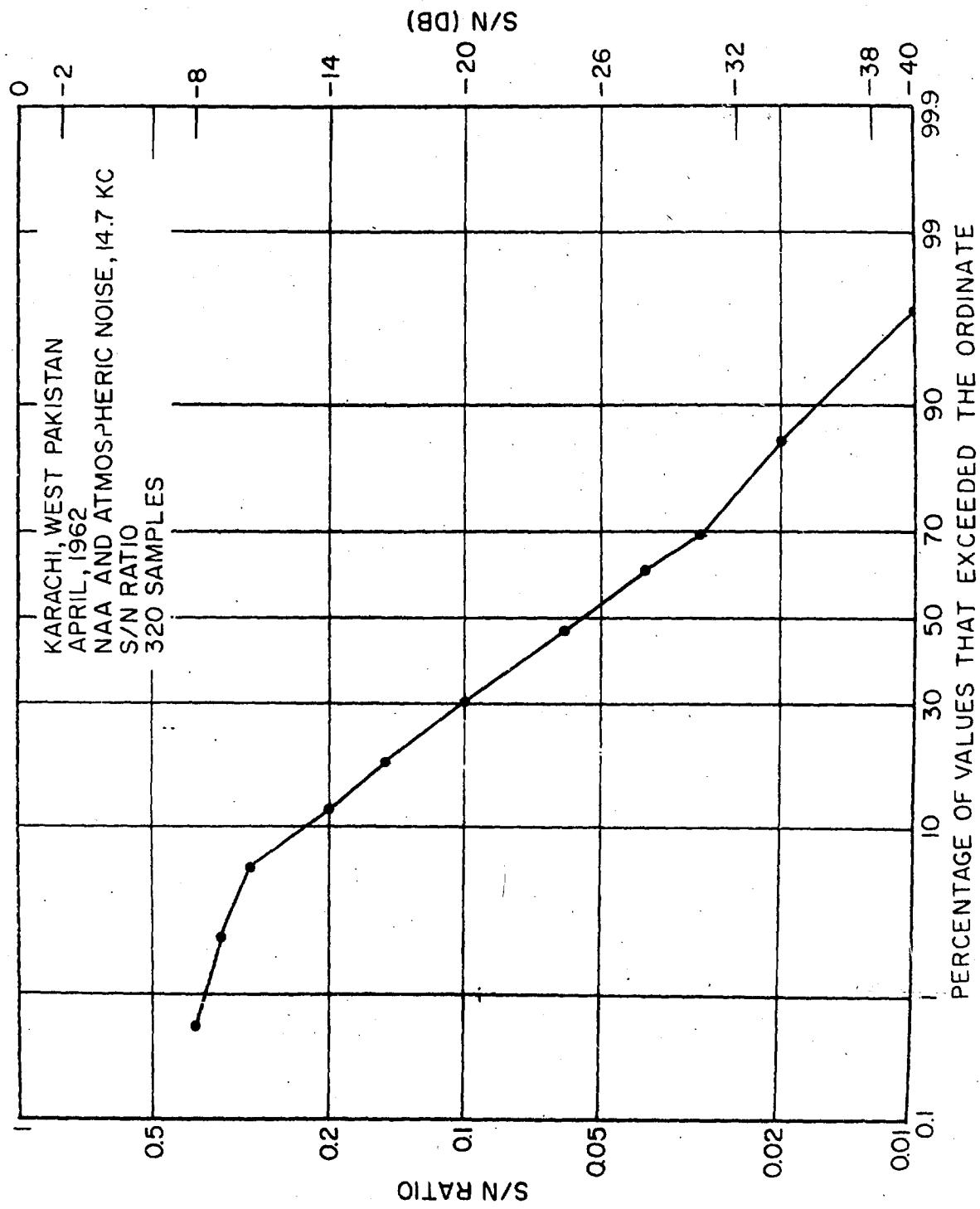


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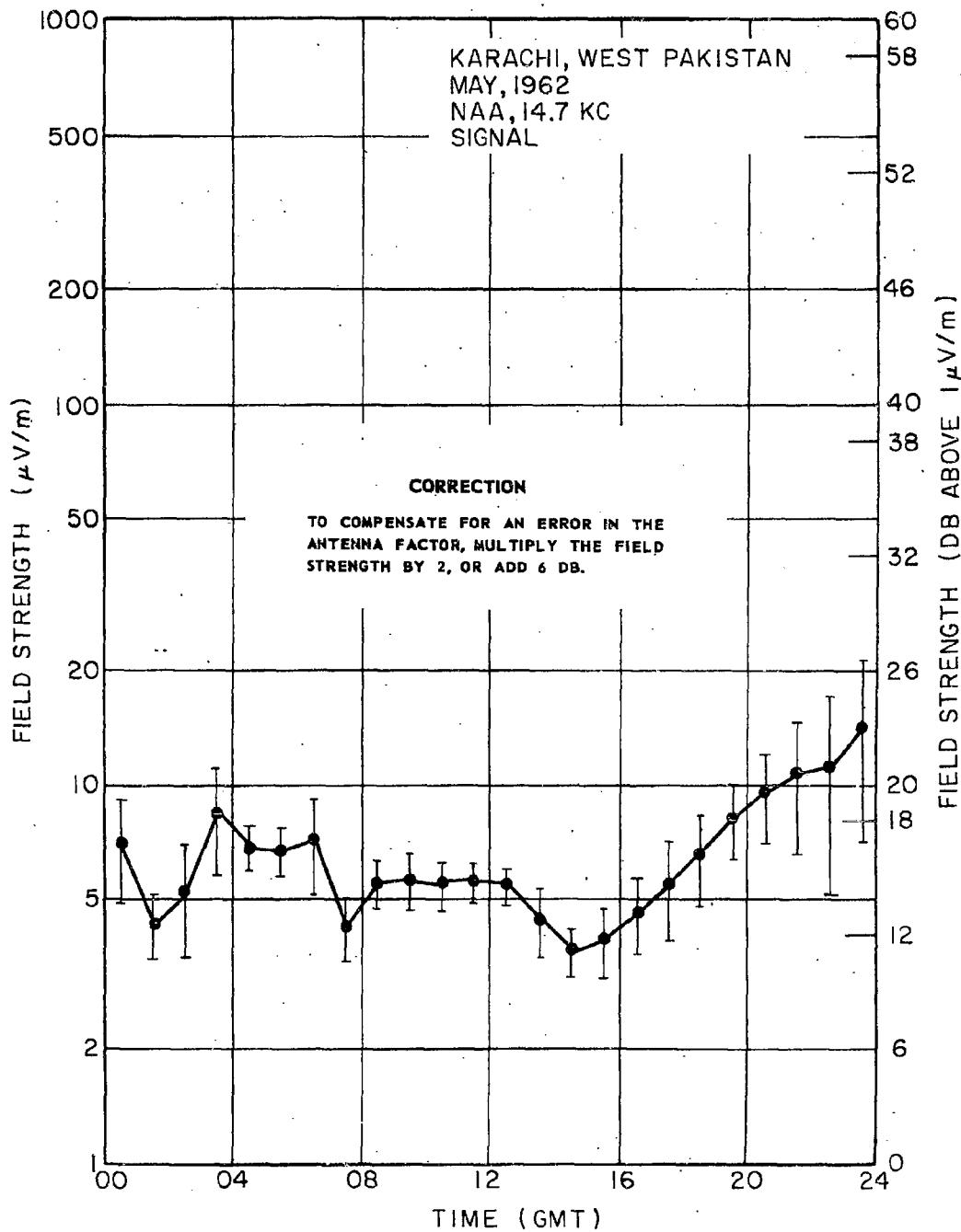


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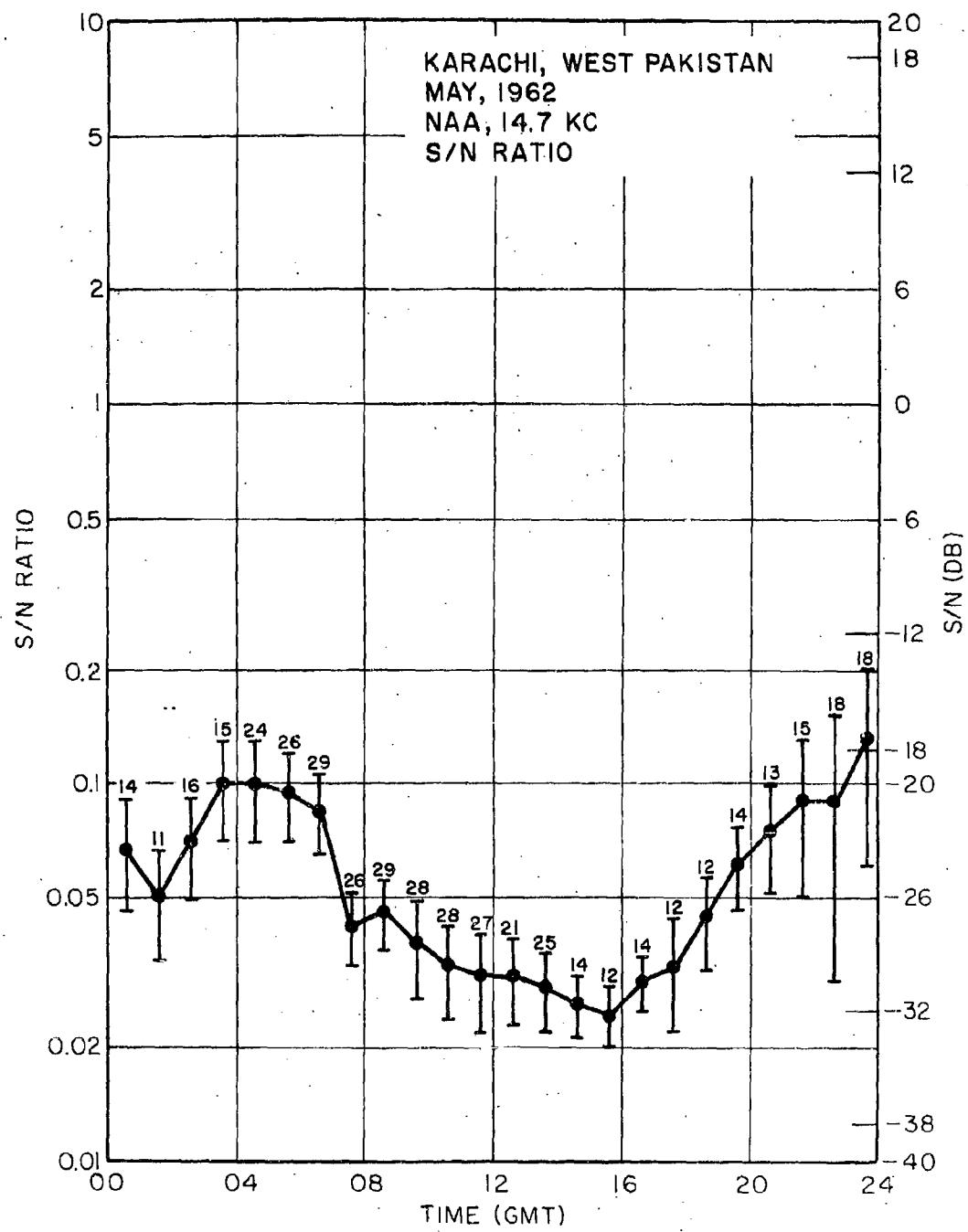


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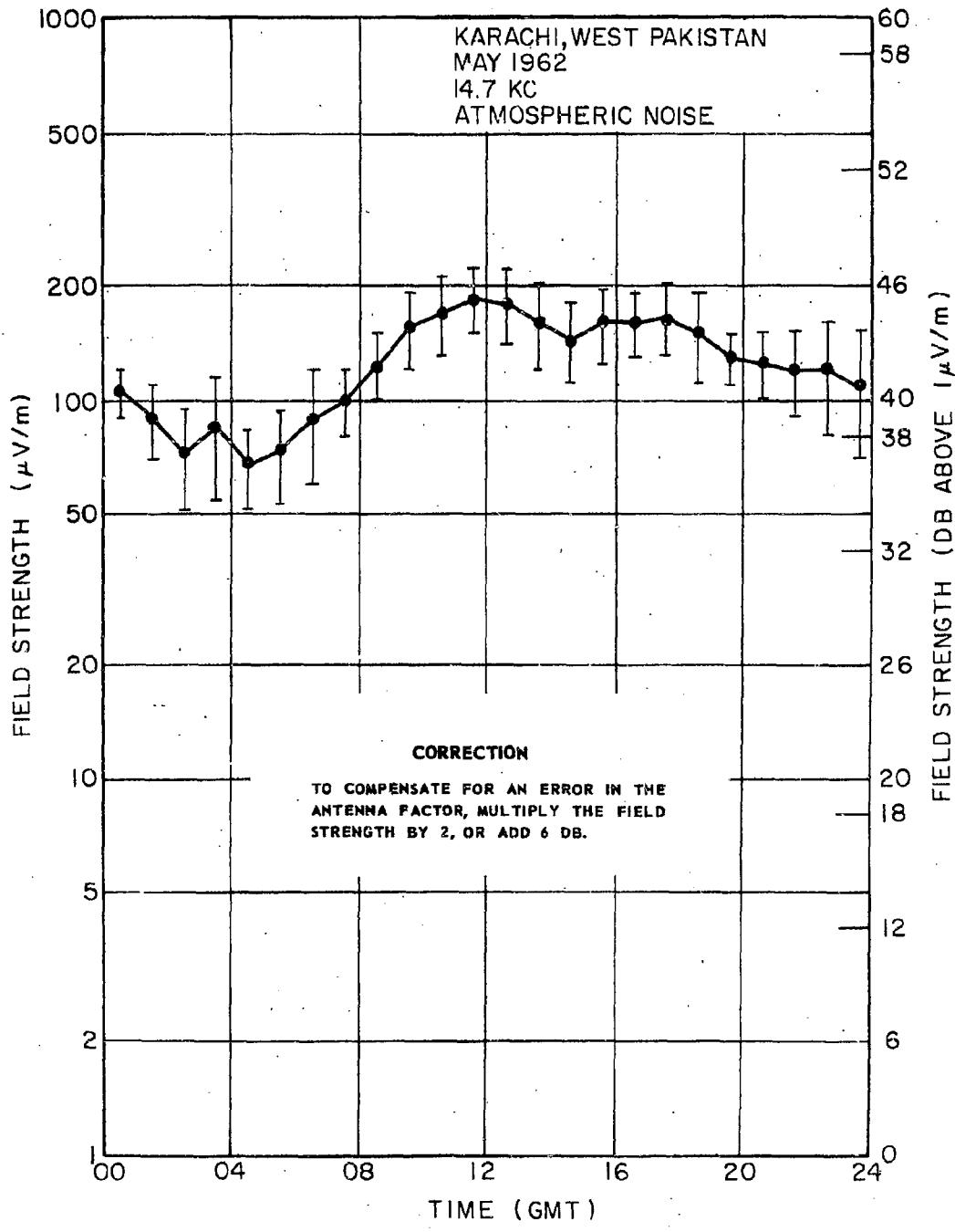


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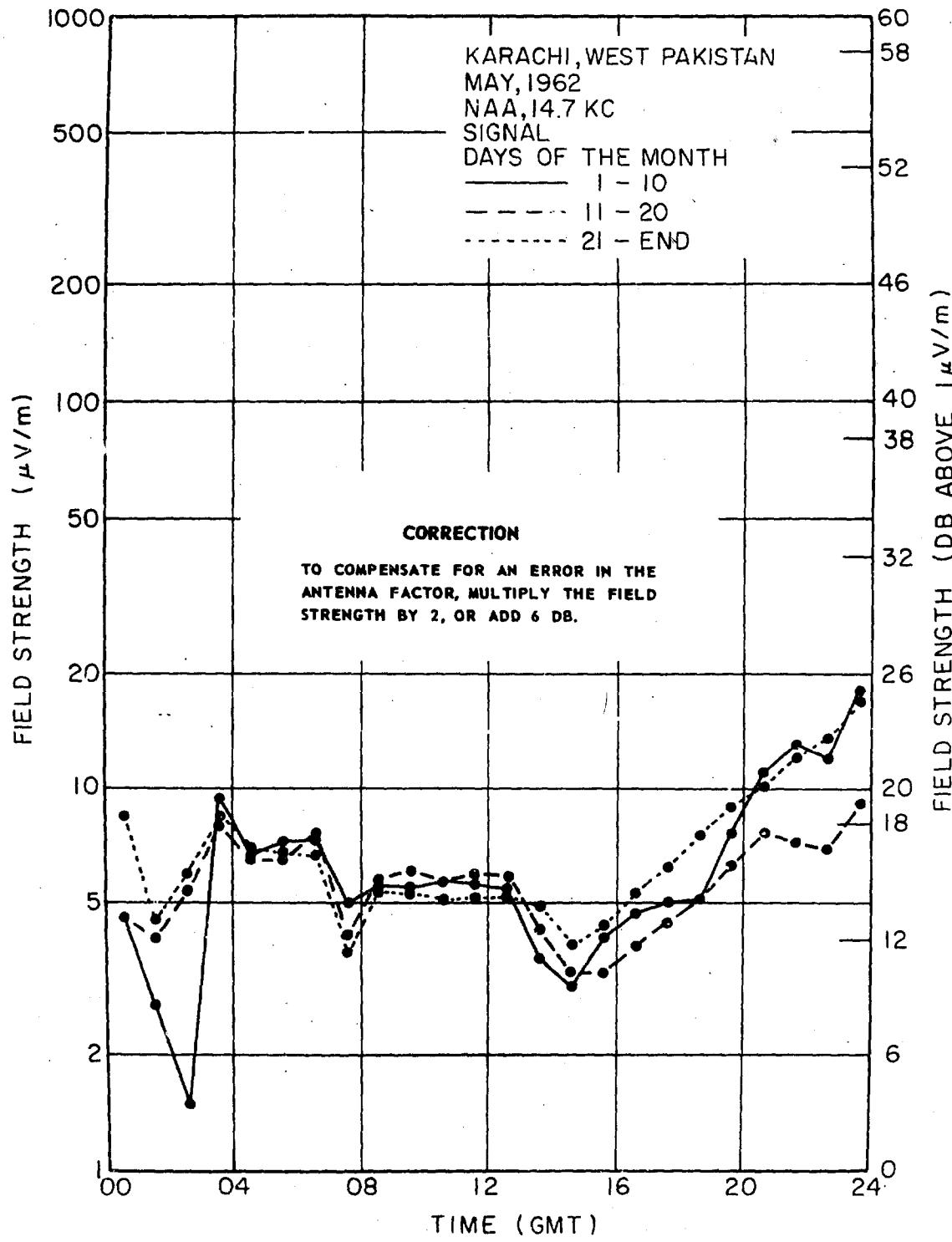


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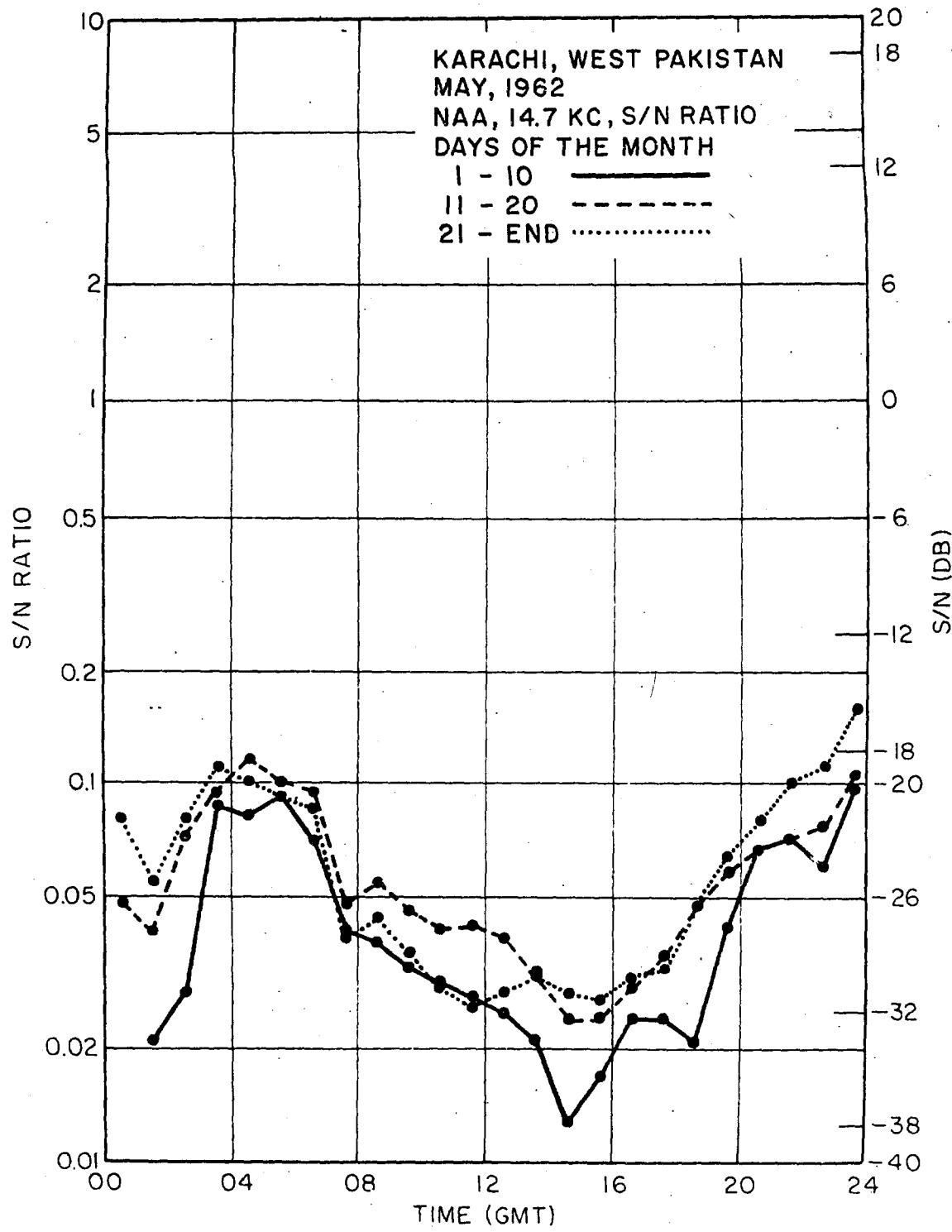


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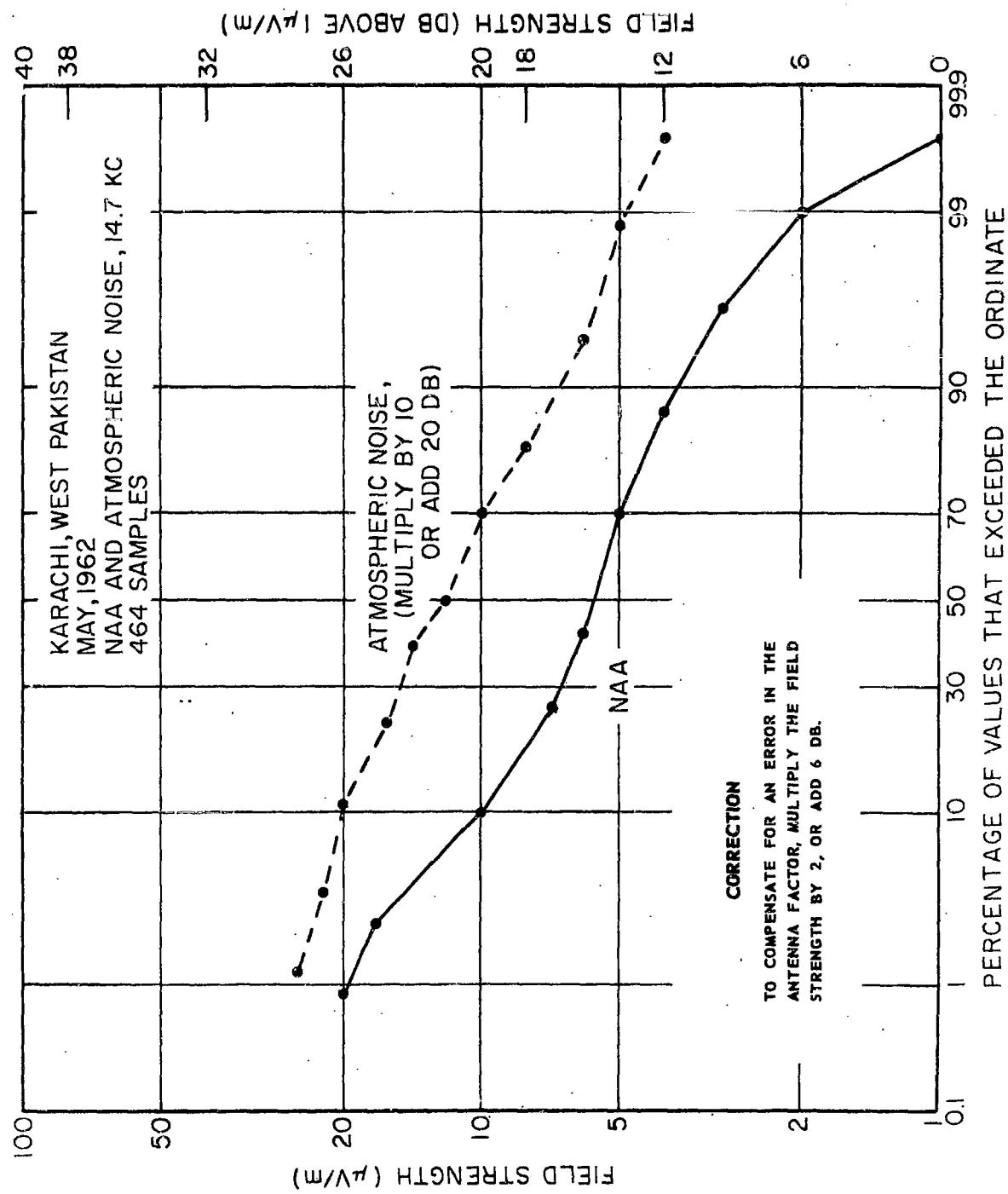


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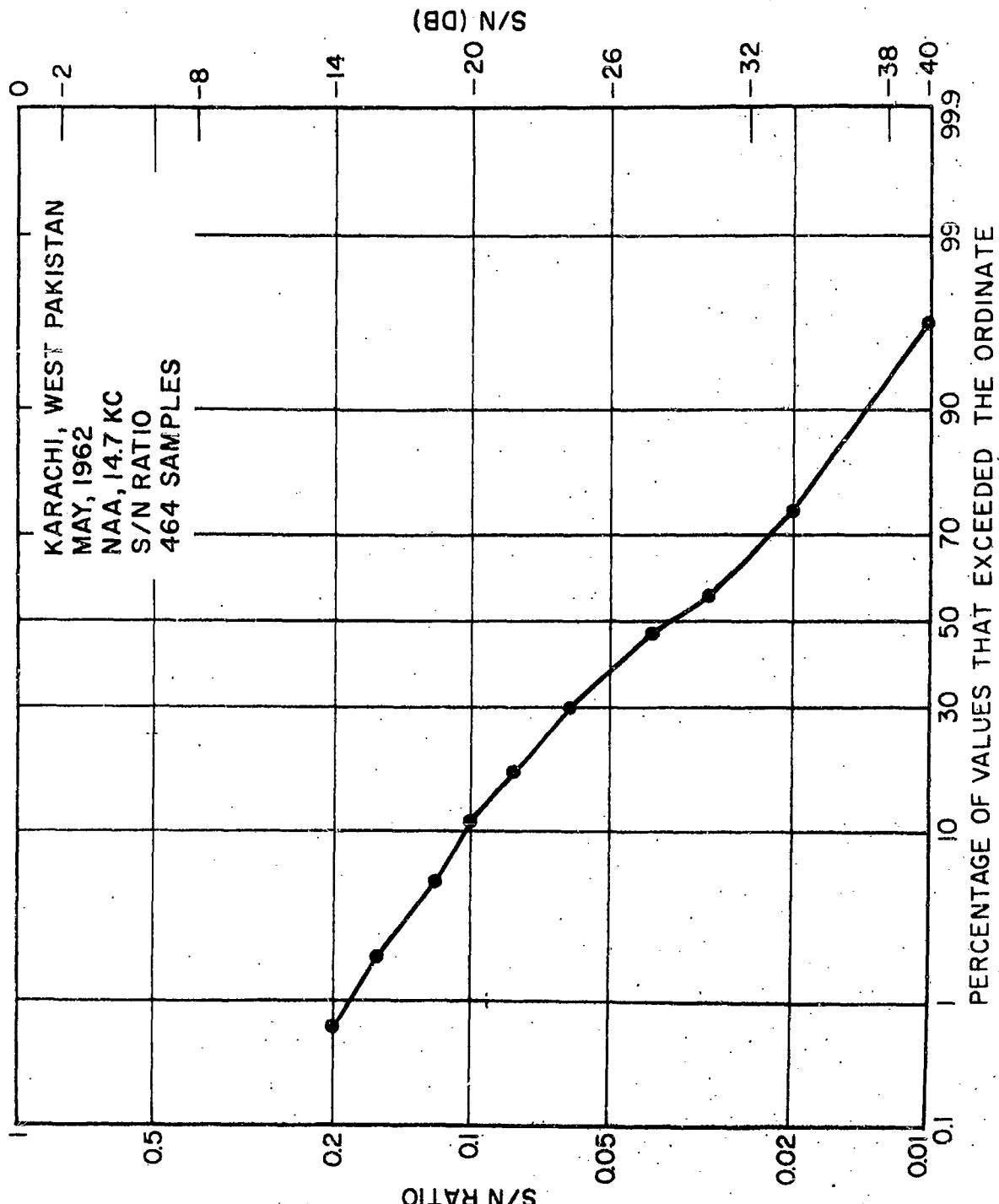


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-- 5 - CORPORATE AUTHOR: NAVAL RESEARCH LAB WASHINGTON D C
-- 6 - UNCLASSIFIED TITLE: FIELD STRENGTHS OF SOME VLF TRANSMISSIONS
-- AND ATMOSPHERIC NOISE MEASURED IN EUROPEAN AND ASIAN AREAS MARCH,
-- APRIL AND MAY, 1962
-- 8 - TITLE CLASSIFICATION: UNCLASSIFIED
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-- 10 - PERSONAL AUTHORS: GARNER,W. E. ;RHOADS,F. J. ;SCHAUER,R. L. ;
-- 11 - REPORT DATE: 29 OCT 1964
-- 12 - PAGINATION: 84P MEDIA COST: \$ 7.00 PRICE CODE: AA
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